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BLE latency under heavy interference

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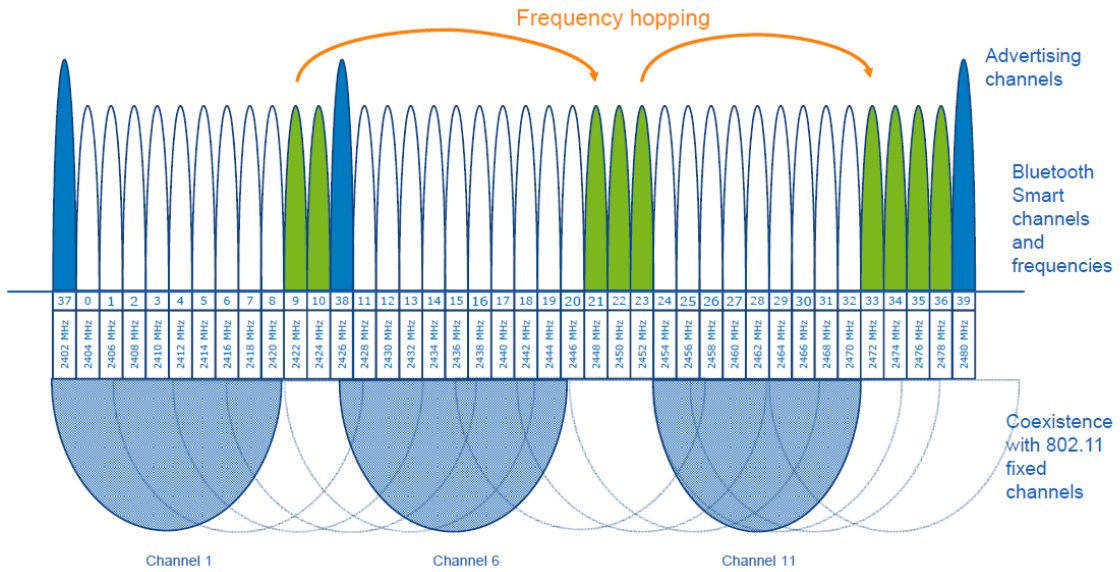
Objective

- NGC-TF presented several studies regarding BLE latency under interference
- Coexistence of several BLE based systems is no problem
- The main source of interference for BLE are Wi-Fi APs operation nearby
- Wi-Fi has higher power and overlaps with BLE spectrum
- The objective is to identify how **heavy** Wi-Fi interference affects BLE communication latency



Latency measurements using medium power setup

BLE PERIPHERAL, BLE SERVER

PRx

nRF52840 Dongle

UART

LATENCY MEASUREMENTS

Host CPU

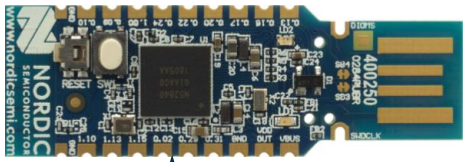
VIRTUAL UART CONNECTION

ROUND TRIP

BLE CENTRAL, BLE CLIENT

PTx

nRF52840 Dongle



UART

Host CPU

Latency measurement

MAX. CONNECTION INTERVAL:
7.5 MSEC

SLAVE LATENCY:
0

PROFILE: POWER RECEIVER

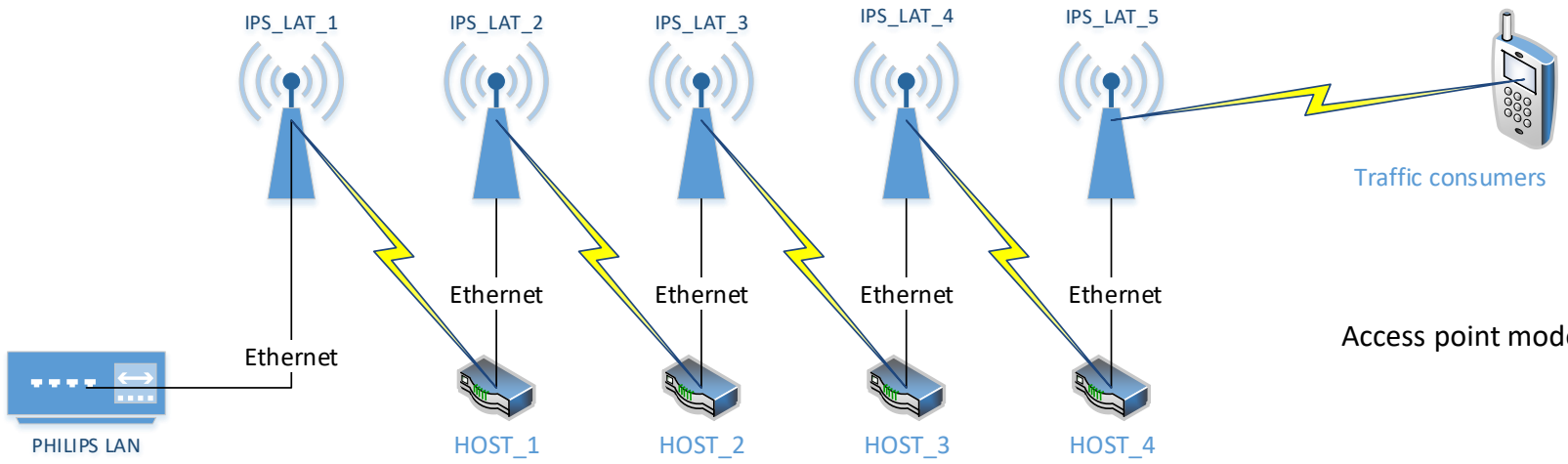
SERVICE: UART ----► 128-BIT UUIDs

CHARACTERISTIC: RX ----► PROPERTIES: WRITE

CHARACTERISTIC: TX ----► PROPERTIES: NOTIFY

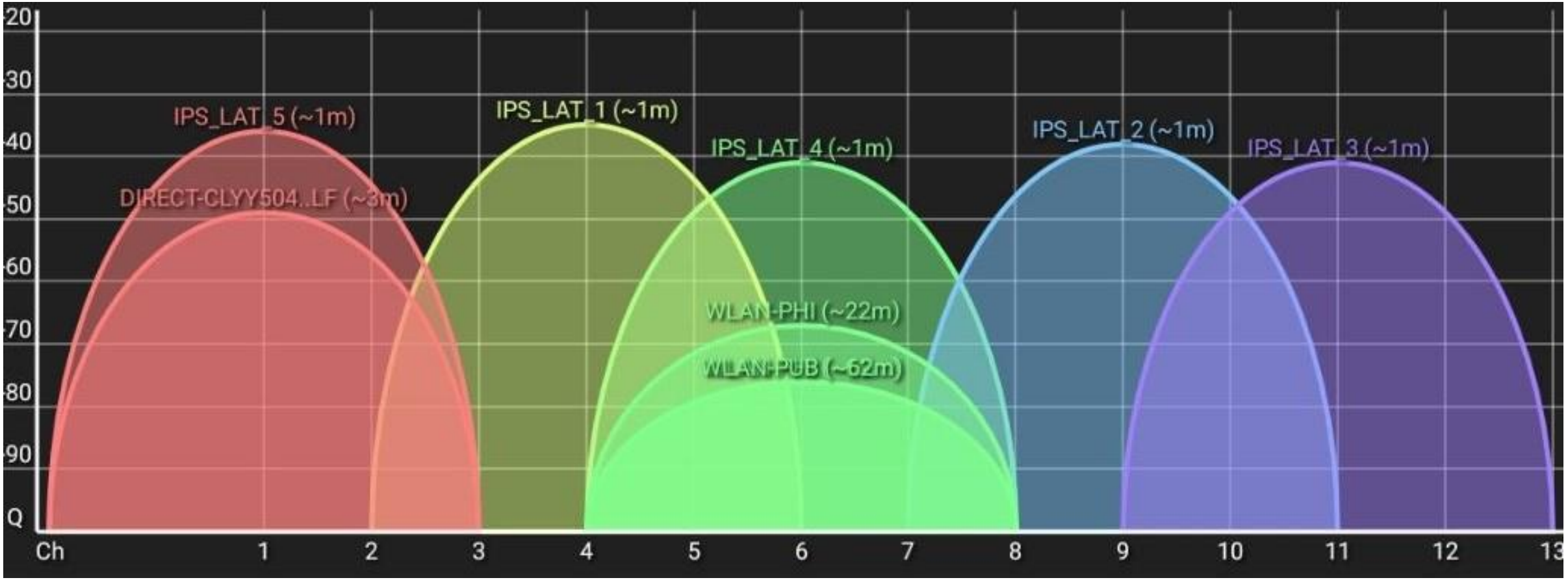
Interference source setup

- Test setup has 5 Wi-Fi access points, operating at Wi-Fi channels 1, 4, 6, 9, 11 plus 4 Linux host for chaining
- All routers and access points are chained and connected to Philips LAN
- Heavy traffic generated on all wireless channels.
- Traffic consumers in setup are a laptop and mobile phone streaming 4K videos simultaneously



Access point model: Edimax BR-6428nC N300

Interference source setup – generated spectrum

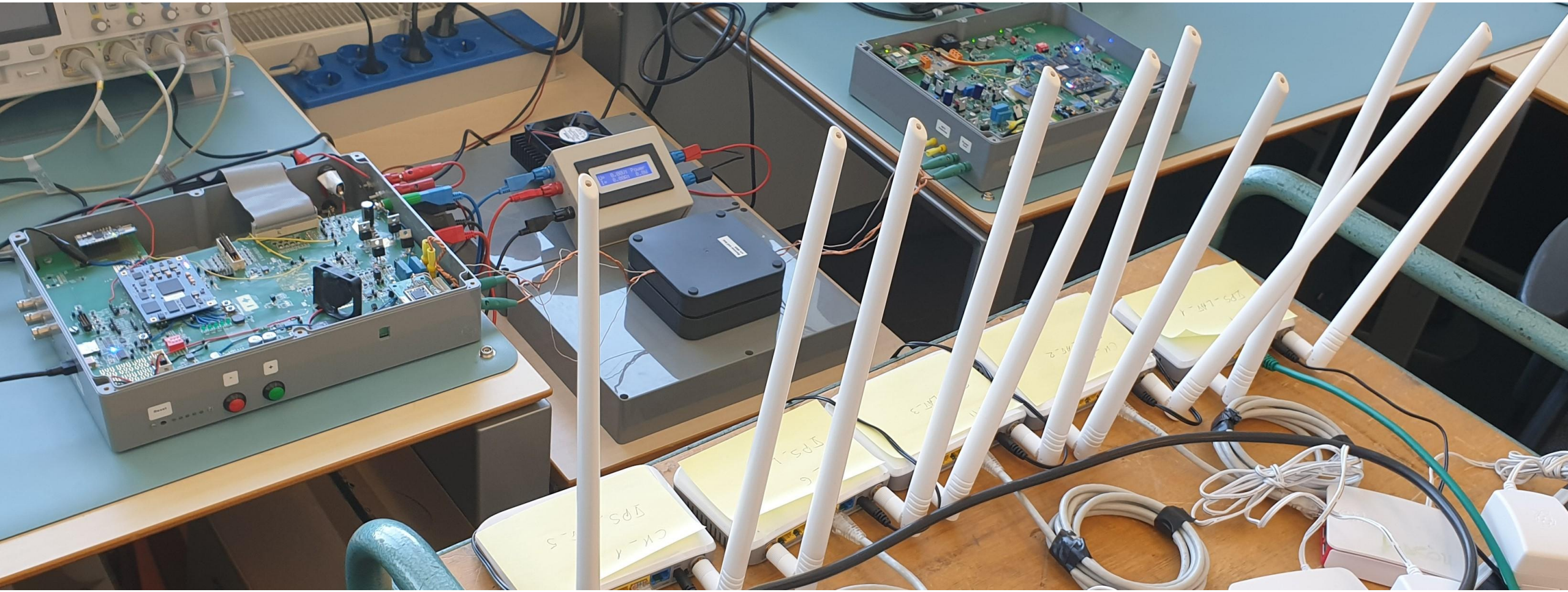


Testing procedure

- The BLE packet round trip will be measured. Round trip time without packet loss**– 15ms.**
- A single measurement takes 5 minutes
- Latency distribution, maximal and average latency during the test will be calculated
- Five test cases:

    - no interference
    - interference setup 0 meters away from wireless power setup
    - interference setup 1 meter away from wireless power setup
    - interference setup 2 meters away from wireless power setup
    - interference setup 3 meters away from wireless power setup
    - interference setup 4 meters away from wireless power setup

Test execution



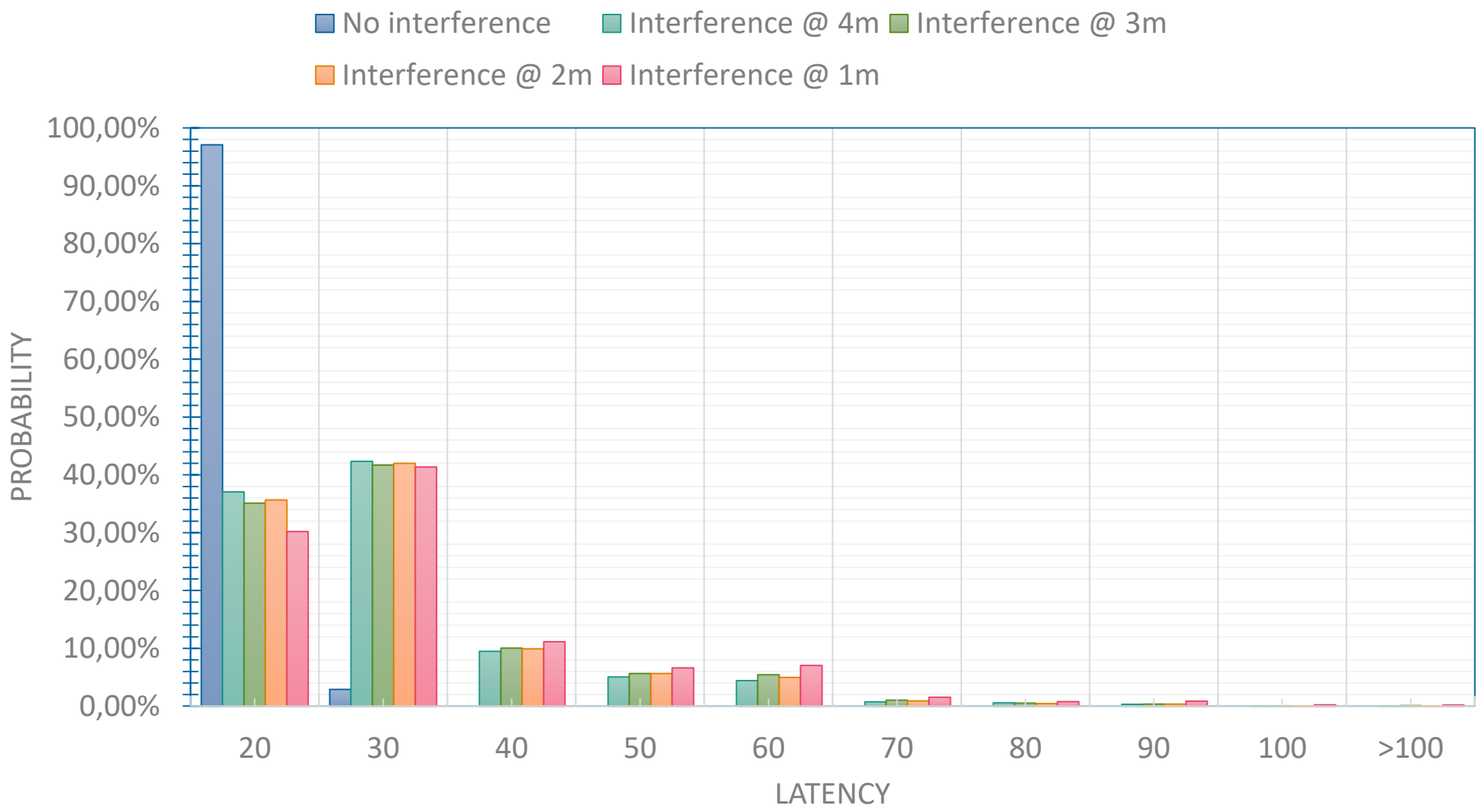
Test results – average and maximal latency

Test condition	Number of packets	Average latency	Maximal latency
No interference	20278	15ms	30ms
Interference setup @ 4m	11664	25ms	120ms
Interference setup @ 3m	11259	26ms	150ms
Interference setup @ 2m	11487	26ms	127ms
Interference setup @ 1m	10788	28ms	128ms
Interference setup @ 0m	9977	30ms	172ms

Test results – latency distribution

Latency, ms	No interference	Interference @ 4m	Interference @ 3m	Interference @ 2m	Interference @ 1m	Interference @ 0m
<20	19690	4320	3953	4096	3260	3152
<30	588	4939	4695	4825	4463	3702
<40	0	1105	1132	1137	1202	1095
<50	0	588	633	649	713	726
<60	0	514	611	571	757	760
<70	0	86	115	102	168	169
<80	0	64	57	53	85	136
<90	0	36	42	43	95	132
<100	0	8	8	2	27	41
>100	0	4	13	9	18	64

Latency distribution, % of overall packets



Conclusions

- BLE link stays alive even under heavy interference
- The transmitted packet is always delivered (even with higher latency)
- Under heavy interference, BLE **average** latency can be **2 times higher** than it has to be without packet loss.
- Under heavy interference, BLE **maximum** latency can be **at least 12 times higher** than it has to be without packet loss.
- Under worst-case condition the probability that at least one of two packets lost is 68%
- In some wireless power delivery applications such an unpredictable latency can be hazardous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