

Projectwork

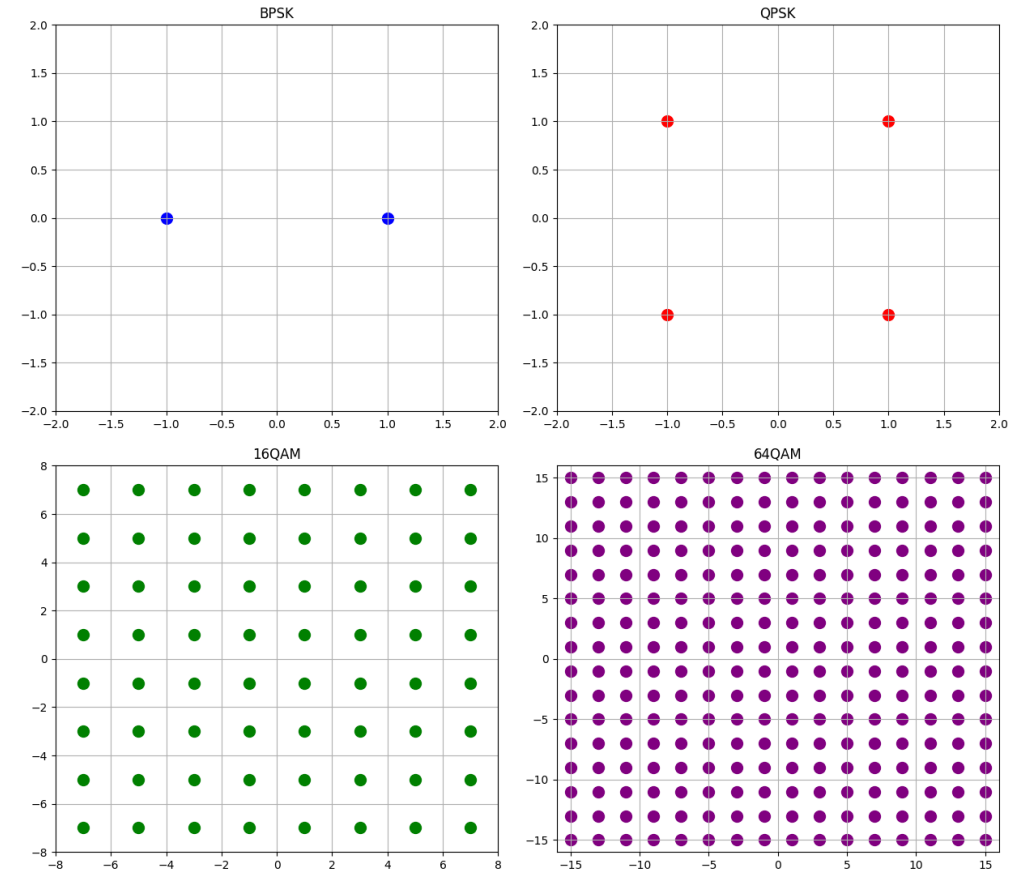
TCP/IP area coverage mit IEEE 802.11ah (Wifi HaLow)

► BFH TI



IEEE 802.11ah (Wifi HaLow)

- ▶ Modulations: BPSK, QPSK, 16QAM, 64QAM
- ▶ Used Anjielo Smart Bridge
- ▶ TaiXin TXW8301 Chipset



Wireless Access Point Ethernet Port Bridge

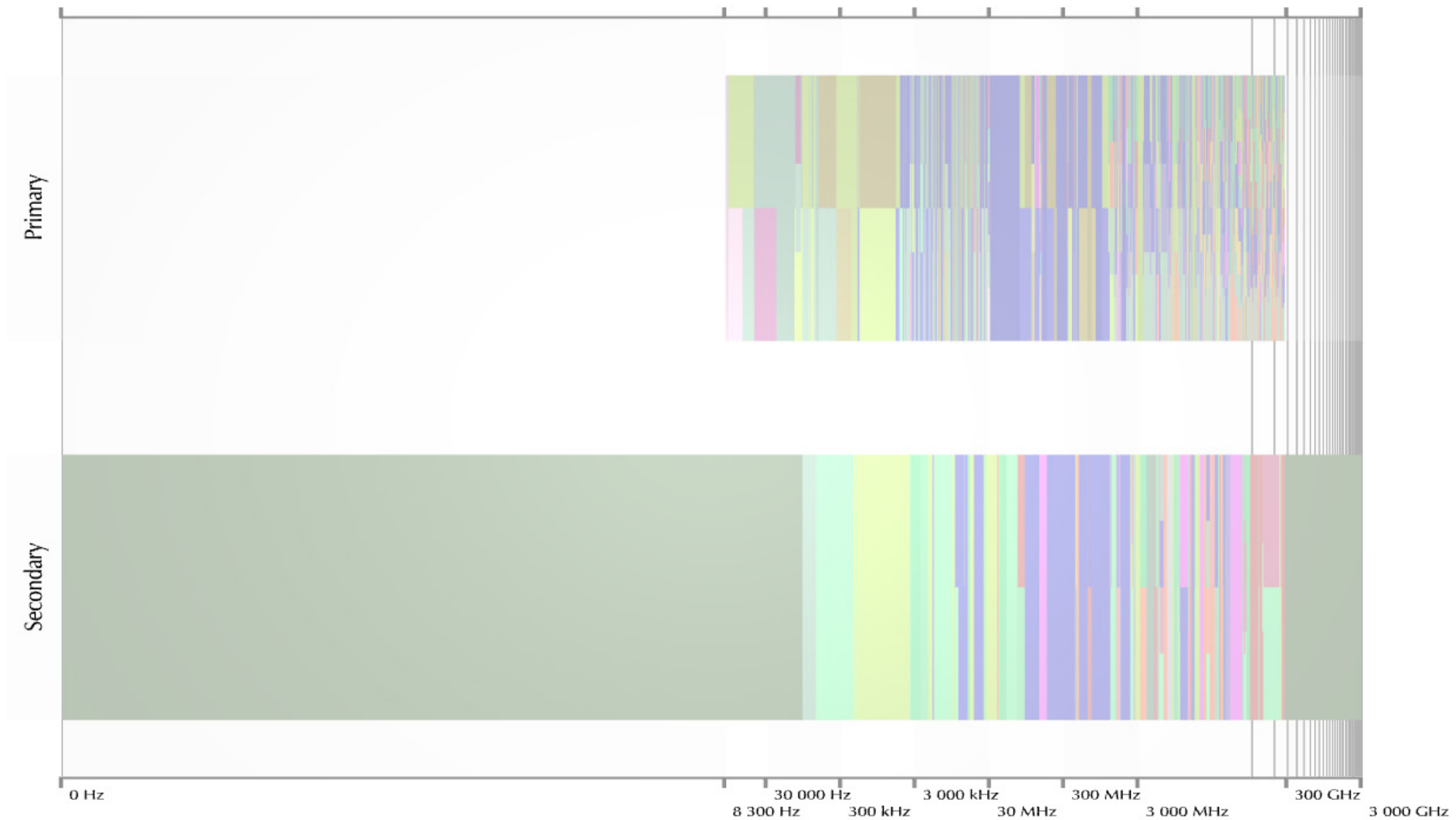
STK-AIR900/ STK-AIR700 spec

<https://anjielo.com/products/2-pack-wireless-access-point-with-ethernet-port-bridge-kit-outdoor-point-to-point-connection-long-range-upto-1-km-for-ip-camera>

Overview

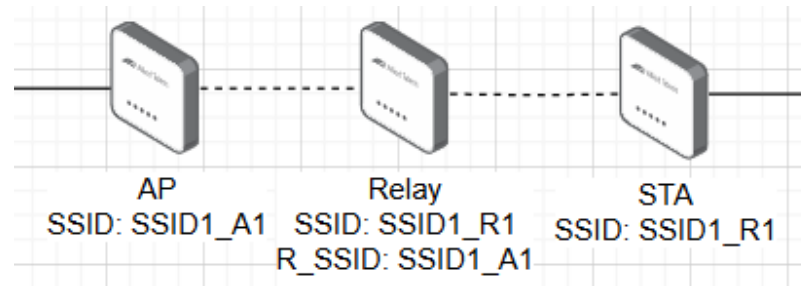
- ▶ Introduction and project objectives
- ▶ Methodology
- ▶ Project results
- ▶ Discussion of results
- ▶ Conclusions and outlook
- ▶ Practical applications

Introduction and project objectives



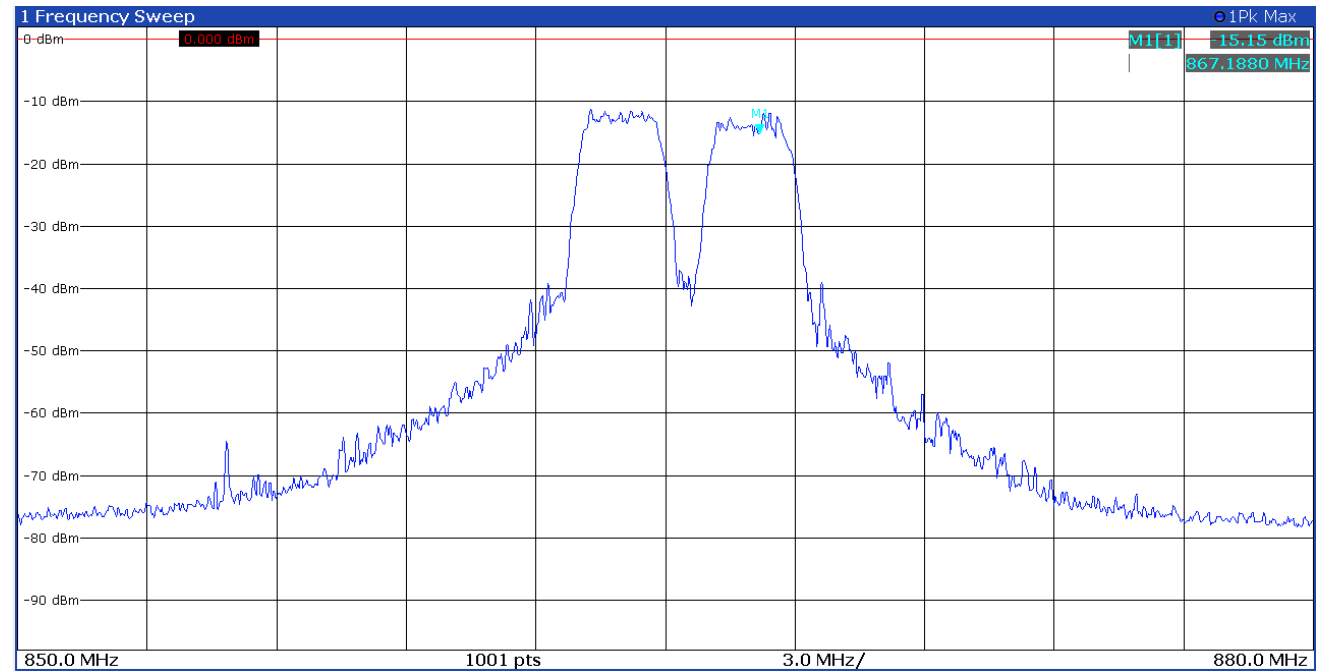
Methodology

- ▶ Measurement setup with Anjielo Smart HaLow Bridge and spectrum analyzers
- ▶ Topologies tested
 - ▶ Relay connections
 - ▶ Roaming connections
- ▶ Measurement parameters
 - ▶ Throughput, latency (ping, jitter), packet loss, receive power (RSSI), transmit powerGPS data
- ▶ Python scripts and tools such as iperf3 and Wireshark

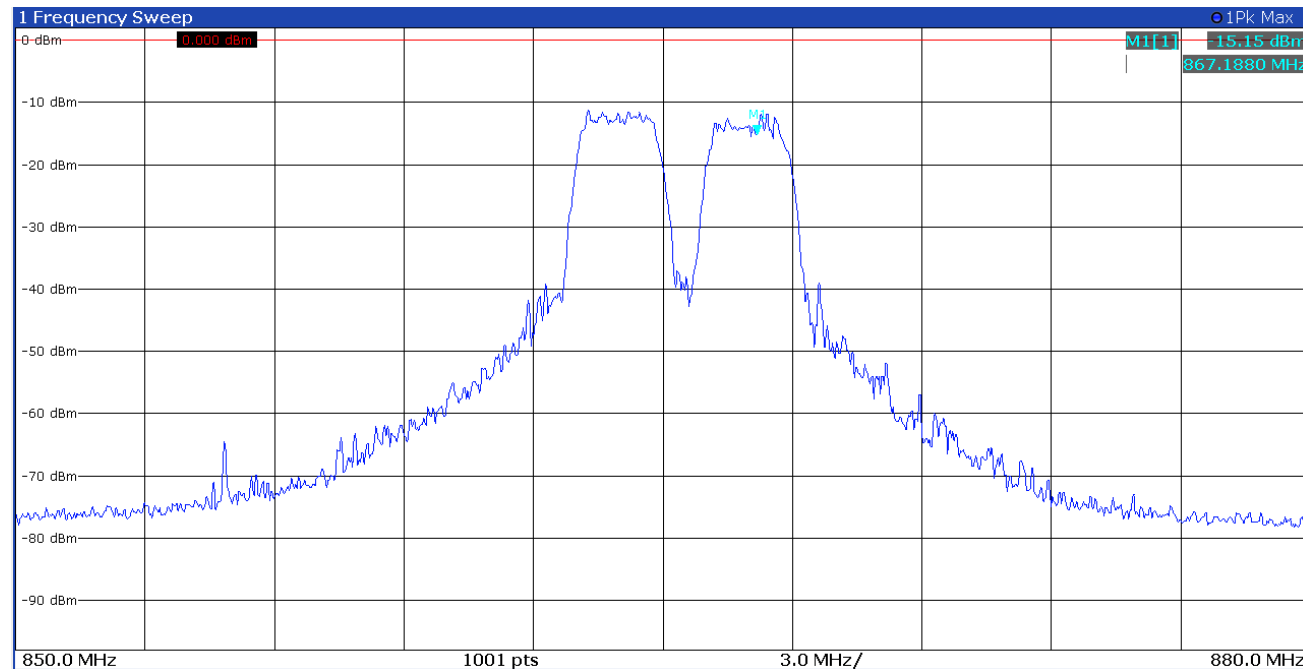


BAKOM Requirements

Aspekt	Requirment
Frequency band	863 - 868 MHz
Bandwith	1 - 2 MHz
Power	14 dBm (25mW)
Duty-Cycle	10 %

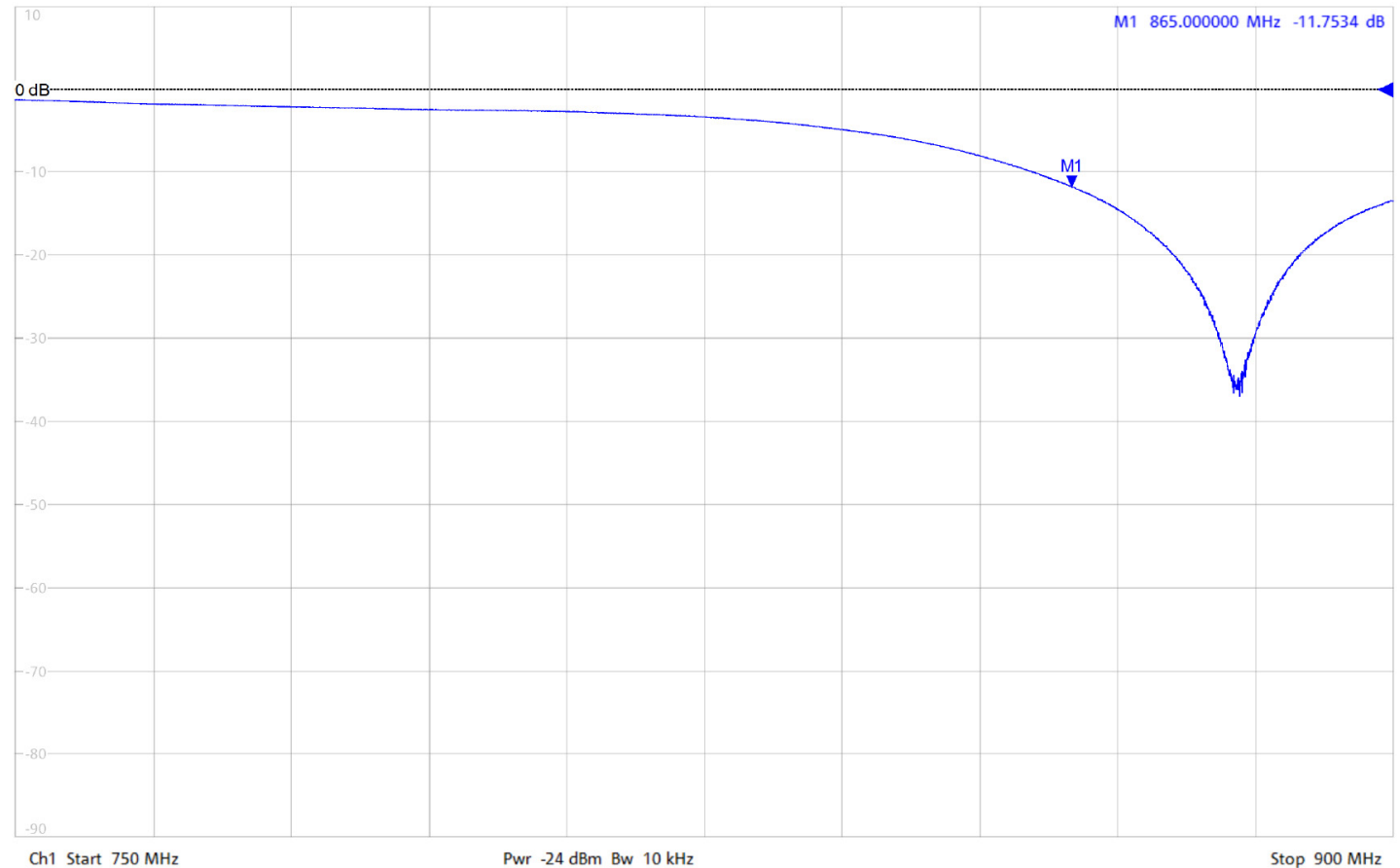


Results – Spectrum Measurements



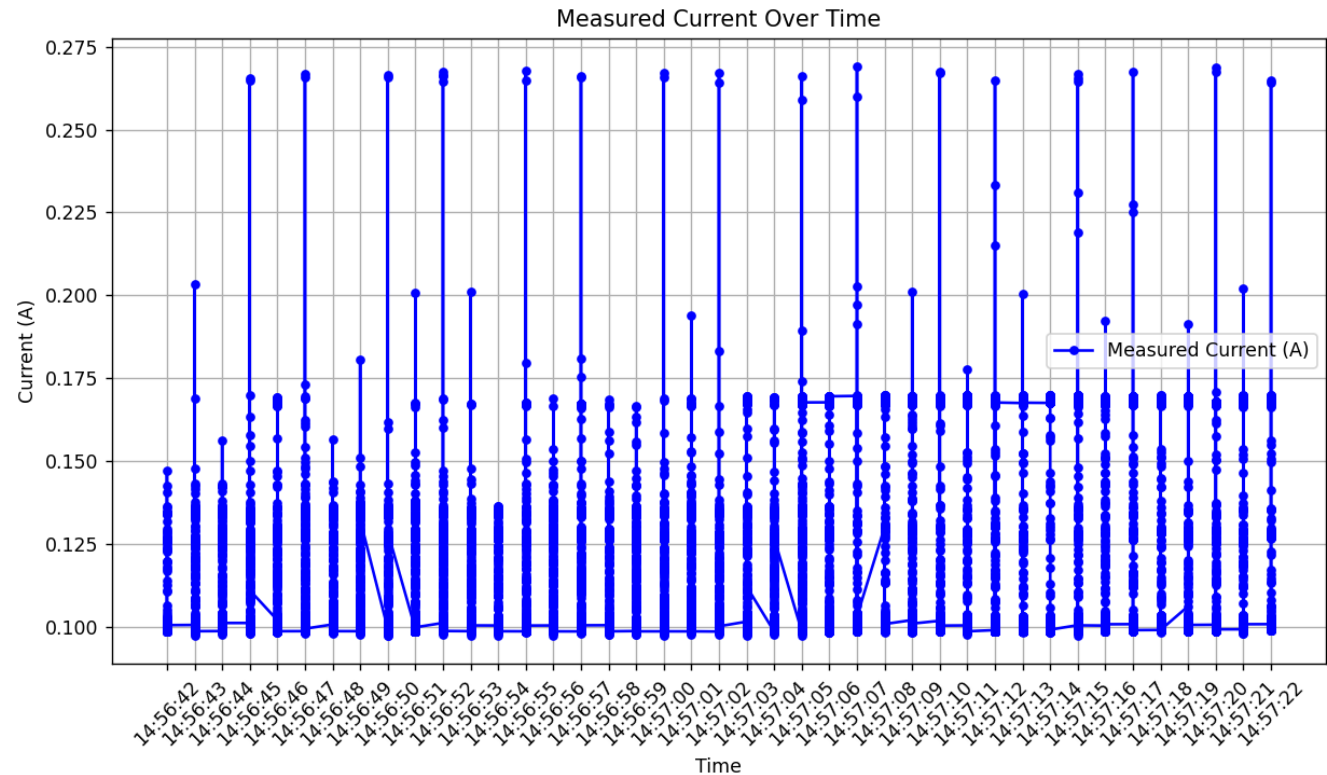
Results – Antenna return attenuation

- ▶ System Network Analyzer
- ▶ Compliance of the system
- ▶ 10 dB \triangleq 10 % of power
- ▶ Here 11.75 dB



Results – Power measurement

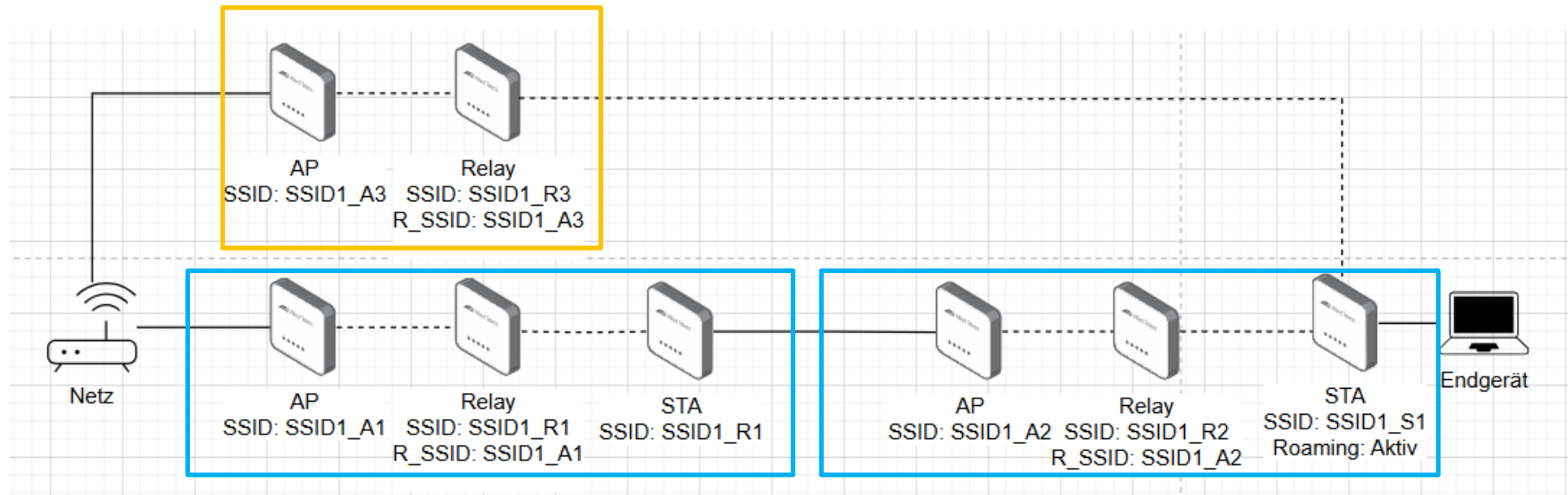
- ▶ Voltage: 5 V
- ▶ Current: 100 – 270 mA
 - ▶ Average: 105.2 mA
 - ▶ Standby: ca. 100 mA
- ▶ Power: 0.526 W



- ▶ Powerbank of 10000 mAh ~ 95 h Runtime

Results – Measurement setup

- ▶ Data transfer rate limited to 0.5 Mbit/s



Results - Measurements

- ▶ Measurement setup
- ▶ Mobile setup
- ▶ Measurement script
 - ▶ iPerf3
 - ▶ GPS
- ▶ Problems with Disconnections
- ▶ iPerf3 timeouts

```

Server listening on 5203 (test #45)
-----
Accepted connection from 192.168.1.2, port 37210
[ 5] local 192.168.1.3 port 5203 connected to 192.168.1.2 port 52822
[ ID] Interval      Transfer     Bitrate     Jitter      Lost/Total Datagrams
[ 5] 0.00-1.00    sec 22.9 KBytes 188 Kbits/sec 22.182 ms 0/8 (0%)
[ 5] 1.00-2.00    sec 42.2 KBytes 345 Kbits/sec 25.808 ms 0/26 (0%)
[ 5] 2.00-3.00    sec 26.5 KBytes 217 Kbits/sec 43.558 ms 0/11 (0%)
[ 5] 3.00-4.00    sec 33.7 KBytes 276 Kbits/sec 32.762 ms 0/4 (0%)
[ 5] 4.00-5.00    sec 38.6 KBytes 316 Kbits/sec 40.260 ms 0/19 (0%)
[ 5] 5.00-6.00    sec 27.7 KBytes 227 Kbits/sec 45.839 ms 0/11 (0%)
[ 5] 6.00-7.00    sec 34.9 KBytes 286 Kbits/sec 34.348 ms 421/448 (94%)
[ 5] 7.00-8.00    sec 36.2 KBytes 296 Kbits/sec 27.573 ms 2127/2157 (99%)
[ 5] 8.00-9.00    sec 30.1 KBytes 247 Kbits/sec 34.641 ms 1952/1967 (99%)
[ 5] 9.00-10.00   sec 21.7 KBytes 178 Kbits/sec 41.528 ms 977/995 (98%)
[ 5] 10.00-11.00  sec 4.82 KBytes 39.5 kbits/sec 67.456 ms 4043/4047 (1e+02%)
[ 5] 11.00-12.00  sec 33.7 KBytes 276 Kbits/sec 74.830 ms 16325/16353 (1e+02%)
[ 5] 12.00-13.00  sec 48.2 KBytes 395 Kbits/sec 52.312 ms 19313/19353 (1e+02%)
[ 5] 13.00-14.00  sec 44.6 KBytes 365 Kbits/sec 43.875 ms 12301/12338 (1e+02%)
[ 5] 14.00-14.97  sec 43.4 KBytes 365 Kbits/sec 138.638 ms 37692/37728 (1e+02%)
-----
[ ID] Interval      Transfer     Bitrate     Jitter      Lost/Total Datagrams
[SUM] 0.0-15.0 sec 194 datagrams received out-of-order
[ 5] 0.00-14.97  sec 489 KBytes 268 Kbits/sec 138.638 ms 95161/95485 (1e+02%)
-----
Server listening on 5203 (test #46)
-----
Accepted connection from 192.168.1.2, port 38988
[ 5] local 192.168.1.3 port 5203 connected to 192.168.1.2 port 44988
[ ID] Interval      Transfer     Bitrate     Jitter      Lost/Total Datagrams
[ 5] 0.00-1.00    sec 13.3 KBytes 109 Kbits/sec 314669765
[ 5] 1.00-2.00    sec 15.7 KBytes 128 Kbits/sec 1359828
[ 5] 2.00-3.00    sec 14.5 KBytes 118 Kbits/sec 626811
[ 5] 3.00-4.00    sec 27.7 KBytes 227 Kbits/sec 142061
[ 5] 4.00-5.00    sec 15.7 KBytes 128 Kbits/sec 613907
[ 5] 5.00-6.00    sec 9.64 KBytes 79.0 Kbits/sec 36633
[ 5] 6.00-7.00    sec 15.7 KBytes 128 Kbits/sec 15839
[ 5] 7.00-8.00    sec 16.9 KBytes 138 Kbits/sec 6413

```

Timestamp	Lat	Long	Alt	Speed	Course	Mode	Fix	Age	Sat	PDOP	HDOP	VDOP	TDOP	Acc	Skew	Relat	Used
2024-12-19T13:44:00.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:01.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:02.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:03.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:04.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:05.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:06.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:07.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:08.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:09.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:10.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:11.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:12.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:13.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:14.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:15.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:16.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:17.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:18.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:19.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:20.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:21.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:22.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:23.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:24.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:25.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:26.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:27.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:28.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:29.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:30.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:31.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0
2024-12-19T13:44:32.000Z	46.833333	7.266667	510	0.0	0.0	0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0	0	0



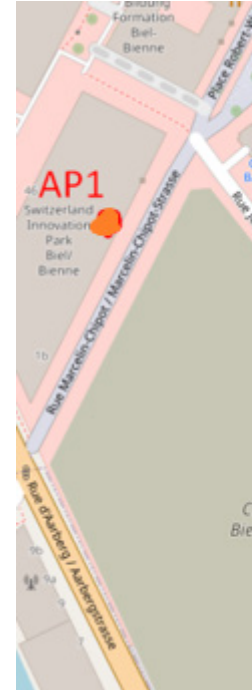
Results – Open field

- ▶ Max. Distance between devices: 1.23 km
- ▶ Coverage: 2.8 km²
- ▶ Data transfer rate: 1.18 MBps at maximum distance
- ▶ Connection interrupted by obstacles such as vegetation and buildings



Results – City

- ▶ Max. Distance between devices: 180 m
- ▶ Coverage: 0.06 km²
- ▶ Low stability
- ▶ Frequency distribution



Results – Forest

- ▶ Max. Distance between devices: 300 m
- ▶ Coverage: 0.27 km²
- ▶ Medium stability



Discussion

- ▶ Limited range with urban obstacles
- ▶ Problematic stability of Anjielo devices
- ▶ Limited data rate (max. 0.5 MBps in complex topologies)

Parameter	Open Field	City	Forest	Einheit
Area	2.8	0.06	0.18	km^2
Max. Distance between	1.23	0.18	0.3	km
Distance with RSSI -80 dBm	0.5	0.15	0.27	km
Average Latency	120	280	70	ms
Stability	4	10	6	Failures p. Intervall

Conclusions and outlook

- ▶ Further projects
 - ▶ Test and comparison with alternative devices
 - ▶ Improvement of measurement methods
 - ▶ Investigating interoperability between different devices
- ▶ The challenges
 - ▶ Stability
 - ▶ Range problems in urban areas
- ▶ WiFi HaLow offers great potential for IoT

Thank you to all the involved people 😊

Questions?
