TECHNICAL NOTE

Throughput test of 7 WiFi routers

Telenor A/S

Report no.: 120-36553-1

Report responsible

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OVERVIEW

Title	Throughput test of 7 WiFi routers
Task no.	120-36553
Report no.	120-36553-1
Client	Telenor A/S Frederikskaj 8 2450 København SV Denmark Tel.: 7212 1212
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1 Introduction

On request from Telenor A/S measurement of 7 different WiFi routers has been performed. The test was performed in a shielded anechoic chamber with introduced scatters for enabling MIMO capability. Throughput was tested against 8 different targets in 2 different configurations.

Test set-up, method, targets, and software is provided by Telenor A/S.

2 Test results

Below test results can be found. For description of test set-up, case and method please refer to section 3.

Test case	1	2	3	4	5	6		7	
Client	Apple iPhone 11 pro	Samsung Galaxy S20+	Huawei P40	OnePlus 8T	Lenovo T470 w. Intel Wi-Fi 6 AX200	Lenovo T470 w. Intel Wi-Fi 6 AX200	Lenovo L470 w. Intel Wireless AC 9260	Xiaomi MI 8	Sony Xperia H8266
Test objects	Below Throughput in Mbit/s								
Icotera i4882	667	688	1270	834	1320	1050	841	532	539
Kaon DG2200	578	611	669	609	664	294	279	263	259
SagemCom F@st 3890	670	666	652	652	589	348	264	345	355
Technicolor DGA4330	100	681	766	122	699	393	283	352	302
Kaon DG3420TD	555	563	118	607	540	303	268	495	565
Icotera i4850	551	553	114	569	657	331	318	280	295
Zyxel VMG3925-10A	584	488	521	504	465	354	421	335	302

3 Test set-up

In Figure 3.1 a schematic of the test set-up can be seen. Test cases for both one and two clients have been defined for measurement of absolute maximum throughput to a single device and effect of further loading of wireless network.

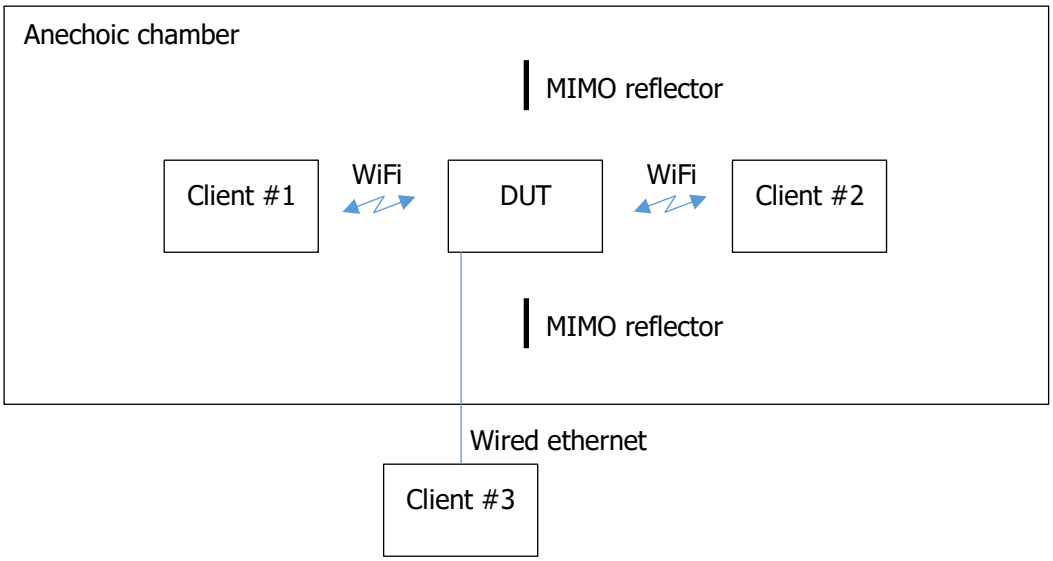

Figure 3.1 Schematic of test set-up. Client #2 is only present during multiuser test cases.

Throughput test was performed with Iperf3. With client #1 and #2 running in server mode. Throughput test was started from client #3. Below the exact command with parameters is stated.

iperf3 -c <ip of client #1 or #2> -P4 -w2m -O 5 -t 60

This starts a test with 4 parallel streams. A test duration of 65 seconds with the first 5 seconds omitted from average throughput calculation.

For multiuser tests with two WiFi clients an iperf client for each WiFi client was started simultaneously in its own terminal window.

The MIMO scatters located in the chamber consisted of two aluminum sheets measuring 0.5m x 0.5m for placing see Figure 3.2 and Figure 3.3

Manufacturer	**Model**
Apple	iPhone 11 pro
Samsung	Galaxy S20+
Huawei	P40
OnePlus	8T
Lenovo / Intel	T470 / Wi-Fi 6 AX200
Lenovo / Intel	L470 / Wireless AC 9260
Xiaomi	MI 8
Sony	Xperia H8266
HP / QNAP systems	EliteBook 840-G3 / QNA-UC5G1T

Table 3.1 Test clients

The test clients were combined in 7 test cases as listed in *Table 3.2*

Test case no	Client #1	Client #2	Client #3
1	Apple iPhone 11 pro	Not present	HP / QNAP systems EliteBook 840-G3 / QNA-UC5G1T
2	Samsung Galaxy S20+	Not present	HP / QNAP systems EliteBook 840-G3 / QNA-UC5G1T
3	Huawei P40	Not present	HP / QNAP systems EliteBook 840-G3 / QNA-UC5G1T
4	OnePlus 8T	Not present	HP / QNAP systems EliteBook 840-G3 / QNA-UC5G1T
5	Lenovo / Intel T470 / Wi-Fi 6 AX200	Not present	HP / QNAP systems EliteBook 840-G3 / QNA-UC5G1T
6	Lenovo / Intel T470 / Wi-Fi 6 AX200	Lenovo / Intel L470 / Wireless AC 9260	HP / QNAP systems EliteBook 840-G3 / QNA-UC5G1T
7	Xiaomi MI 8	Sony Xperia H8266	HP / QNAP systems EliteBook 840-G3 / QNA-UC5G1T

Table 3.2 Test cases

Manufacturer	Model	S.no
Icotera	i4882	4882700000413
Kaon	DG2200	071201600057588
SagemCom	F@st 3890	DM1815618005326
Technicolor	DGA4330	CP2007RA6JE
Kaon	DG3420TD	BS10064932001675
Icotera	I4850	4850002520148099
Zyxel	VMG3925-10A	S200Y27012989

Table 3.3 Test objects

Figure 3.2 Picture of test set-up with single client

Figure 3.3 Picture of test set-up with two clients

TECHNICAL NOTE

Range test of 7 WiFi routers

Telenor A/S

Report no.: 120-36553-2

Report responsible

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OVERVIEW

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Task no.	120-36553
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Client	Telenor A/S Frederikskaj 8 2450 København SV Denmark Tel.: 7212 1212
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1 Introduction

On request from Telenor A/S, measurement of 7 different WiFi routers has been performed. The test was performed in a reverberation chamber with its fading profile adjusted for emulation of real case scenario. The maximum throughput was limited to approximately 1000 Mbit/sec by hardware, not relevant for the WiFi performance.

2 Test results

Below, the test results can be found. The test results are stated as an average measured throughput with associated standard deviation of measurements. Average is a well-known concept to most people. However, standard deviation might not be a commonly known term. Standard deviation is a statistical term that describes the spreading of a series of data. In a series of data 68 % of data has value within a range of (±) one standard deviation from the average, and 95.5 % of the data has a value within two standard deviations from the average. As an example, a measurement series with an average throughput of 851 Mbit/sec and a standard deviation of 93 Mbit/sec, there is a probability of 68 % that a single measurement of throughput is in the range from 758 Mbit/sec to 944 Mbit/sec. This means that the probability of the measurement being greater than 758 Mbit/sec is 84 %. The corresponding figures for two standard deviations become 95.5 % probability for a measured throughput between 665 Mbit/sec and 1037 Mbit/sec, and 97.7 % probability that throughput is greater than 665 Mbit/sec.

Estimated indoor range is taken, as the ideal range divided by 3.3. However, this shall be expected to subject to great variance due to building properties and background noise.

For description of test set-up, case and method please refer to Section 3.

Estimated indoor range [m]	0.1	0.4	1.3	4.2	13.1	41.6	58.7	82.9	117.1	165.5	233.7
	Throughput average / standard deviation [Mbit/s]										
Icotera i4882	851 / 93.3	860 / 127	877 / 92.7	973 / 63.3	598 / 181	315 / 52.1	294 / 93.1	158 / 33.4	82.9 / 19.3	39.2 / 12.7	7.42 / 7.63
Kaon DG2200	535 / 13.2	535 / 13.9	540 / 14.3	540 / 15.4	400 / 91.2	183 / 39.3	146 / 37.4	55.4 / 29.7	12.0 / 17.5	-[1]	-[1]
SagemCom F@st 3890	628 / 17.8	628 / 16.0	628 / 16.1	623 / 31.6	490 / 37.9	240 / 50.1	155 / 28.4	87.5 / 21.8	64.4 / 22.6	46.9 / 20.1	13.8 / 17.4
Technicolor DGA4330	651 / 17.1	650 / 39.9	655 / 16.3	577 / 142	482 / 147	214 / 94.3	205 / 39.6	163 / 31.0	93.3 / 32.1	43.6 / 14.4	6.99 / 9.18
Kaon DG3420TD	529 / 47.9	534 / 14.4	539 / 15.5	539 / 14.6	487 / 52.8	290 / 62.5	227 / 39.1	120 / 29.2	44.9 / 26.8	13.6 / 19.4	1.22 / 8.77
Icotera i4850	633 / 18.9	632 / 18.1	632 / 21.6	0.00917 / 0.0219	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]
Zyxel VMG3925-10A	596 / 18.9	615 / 23.4	595 / 16.5	579 / 20.2	355 / 77.4	170 / 38.8	73.9 / 24.9	33.0 / 17.9	22.1 / 12.8	9.7 / 11.5	2.1 / 4.21

[1]The router and client was not able to maintain WiFi connection over a full stirrer rotation.

3 Test set-up

Modern wireless MIMO technology depends heavily on multipath propagation of the wireless signal. Hence, performing test in an anechoic chamber might not represent the actual performance of the system.

For measurement of WiFi range performance the set-up shown in Figure 3-1 was used. The testing was performed in an electromagnetic reverberation chamber. The reverberation offers a multitude of propagation paths. However, fading of signals takes much longer time than real case scenario. The fading profile was adjusted by adding 6 RF absorbers. The reverberation offers many different propagation paths, but not all equally good. The available propagation paths are most sensitive, even small displacement of antennas causes changes in propagation paths.

A reverberation chamber has an electromagnetic stirrer, which can alter all propagation paths inside the chamber except for the direct path between two antennas. To test a multitude of different propagation scenarios, a test of throughput was performed over one full stirrer rotation. An RF absorber was placed between the WiFi client and the router under test since this path can not be altered by the electromagnetic stirrer and elsewise is dominating.

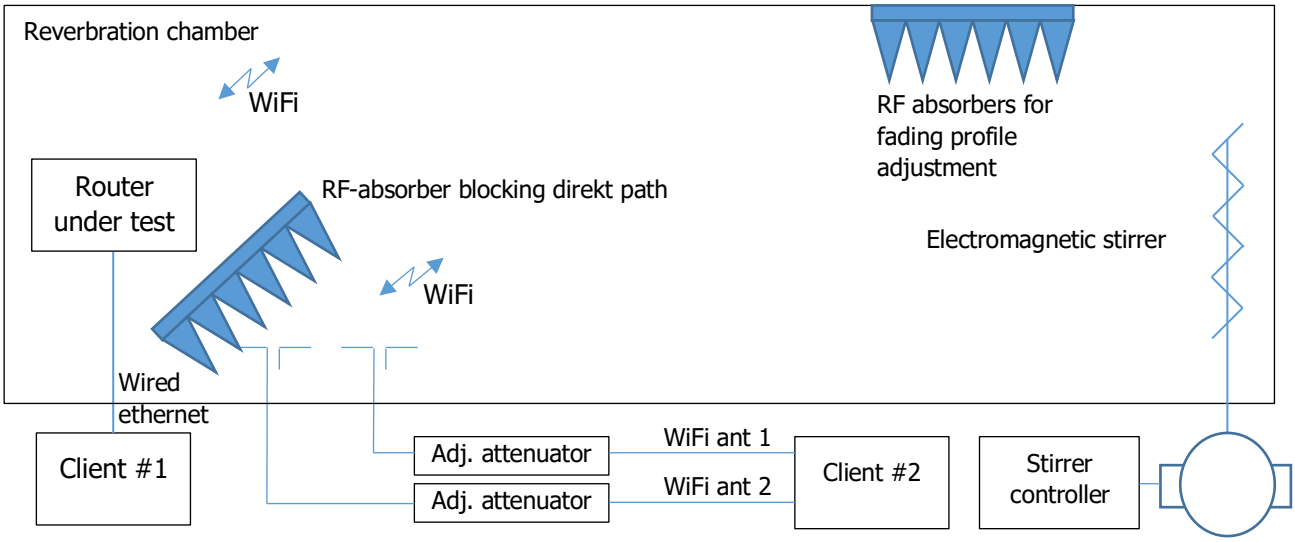


Figure 3-1 Schematic of test set-up. Range increments are simulated by increasing the adjustable attenuators. All measurement is performed over one full stirrer rotation with 193 measurements.

Before test start, the router under test was replaced with an antenna, and path loss between this antenna and the antennas connected to client#2, was measured over one full stirrer rotation and minimum loss was recorded.

Throughput data was collected with iPerf3[1] as on rotation of the stirrer takes 193 seconds this resulted in 193 throughput measurements over one stirrer rotation each covering 1 second of stirrer rotation. Below the exact iPerf3 command can be seen.

iperf3 -c <ip of client> -P10 -O 10 -t 193

This starts a test with 10 parallel streams. A test duration of 193 seconds with the first 10 seconds omitted giving time to synchronize start of stirrer rotation.

The above described test was repeated with increasing attenuation setting of the adjustable attenuators, simulating increased distance between the router under test and client#2. Test was repeated until that connection between the router under test and client#2 could not be maintained during a full stirrer rotation.

[1] Iperf3 is a widely used software that measures throughput between two endpoints

Data was subsequently processed statistically. It has been assumed that the data is distributed in a Gausian shape around an average. However, this might not be completely correct for all cases, especially when throughput is limited either upwards or downwards (e.g. HW limited or throughput approaches zero).

The ideal range was calculated from attenuation setting combined with the minimum value of the loss recorded initially. The ideal range is in real case scenarios reduced by buildings and other obstructions in the propagation path along with higher level of background noise (e.g. adjacent routers operating on the same frequency). The reduction is set to 3.3 in this work but could be anywhere between 1 and 10 depending on the exact location.

Table 3-1 Hardware used

Manufacturer	**Model**
Lenovo / Intel	M920 Tiny[1] / Wi-Fi 6 AX200
Lenovo / QNAP systems	T480 / QNA-UC5G1T

[1]After performing the test, it was discovered that the m2 slot for the WiFi adapter was of a 'x1' type limited to approx. 1000 Mbit / sec. This has therefore limited the measured maximum capacity.

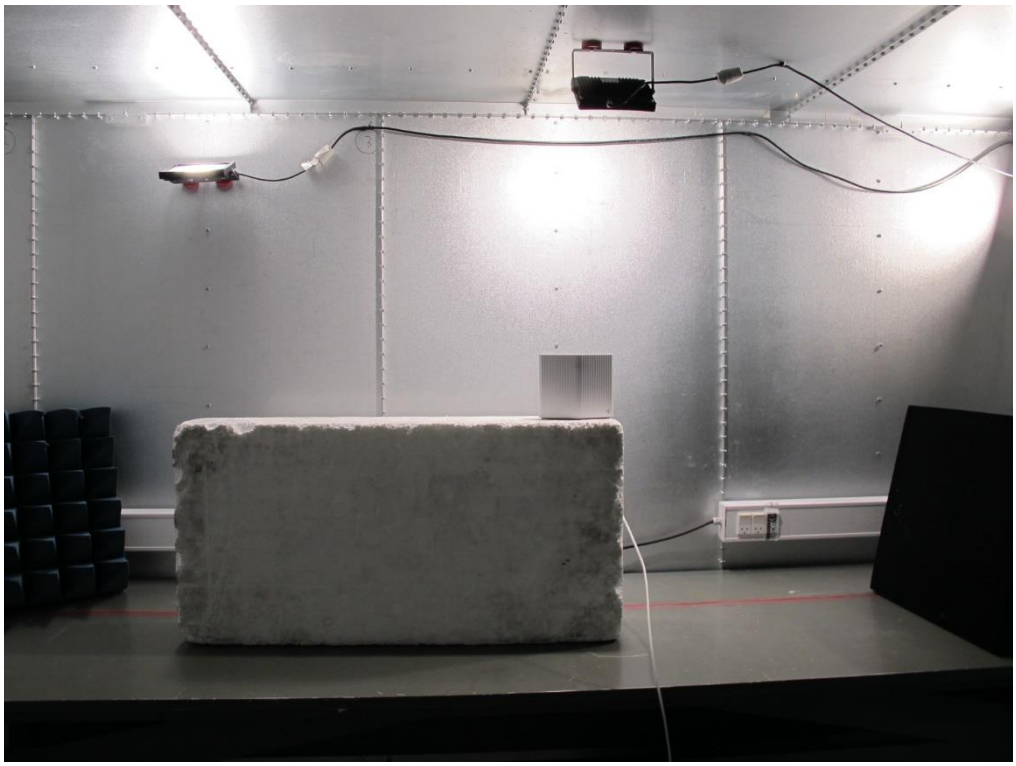
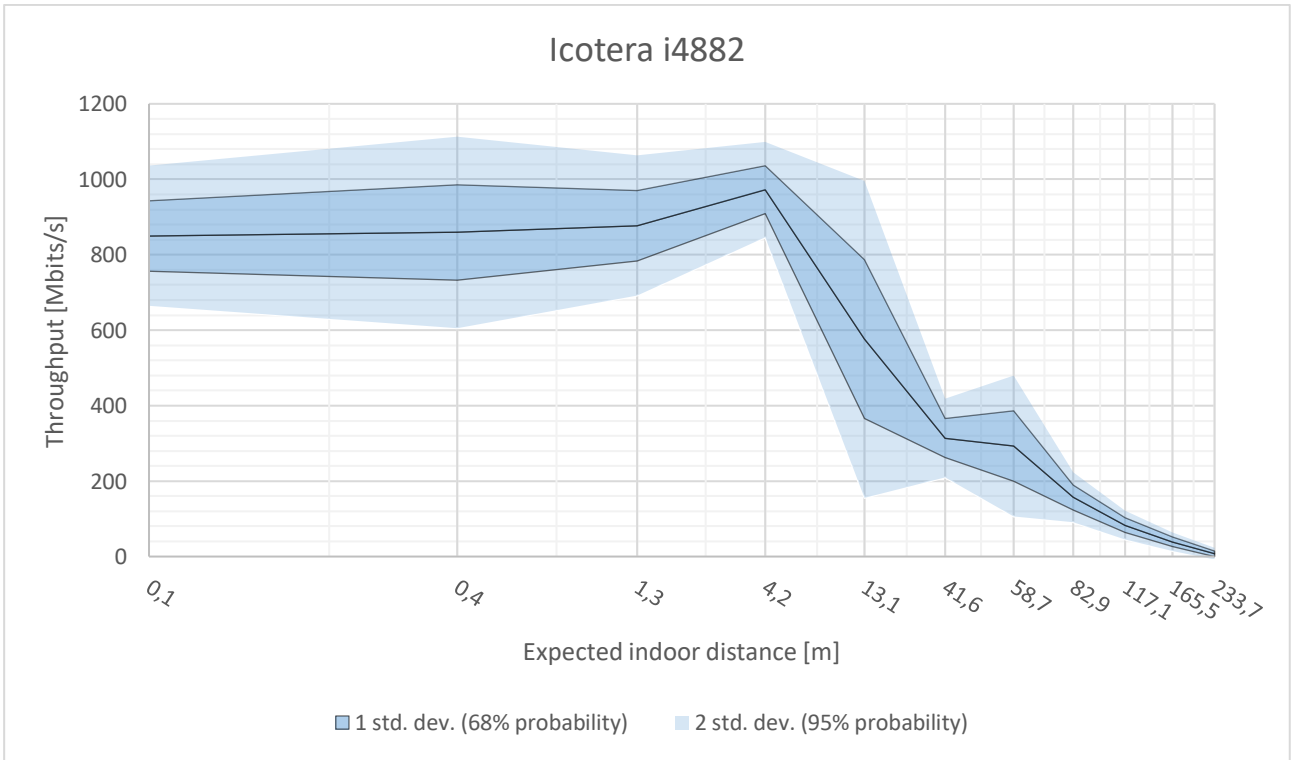


Figure 3-2 Picture of router in test set-up.

4 Test specimens

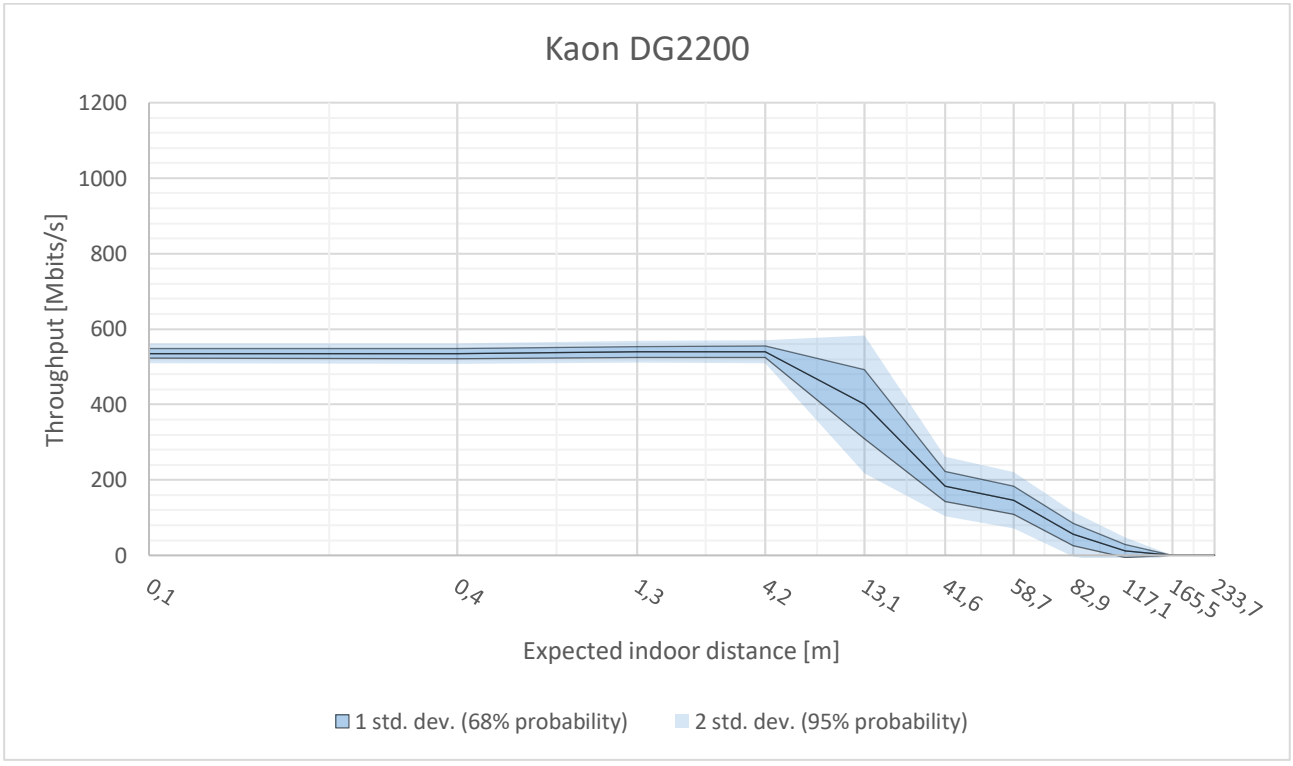
4.1 Icotera I4882

Model / type	I4882
Serial no.	4882700000413
Producent	Icotera



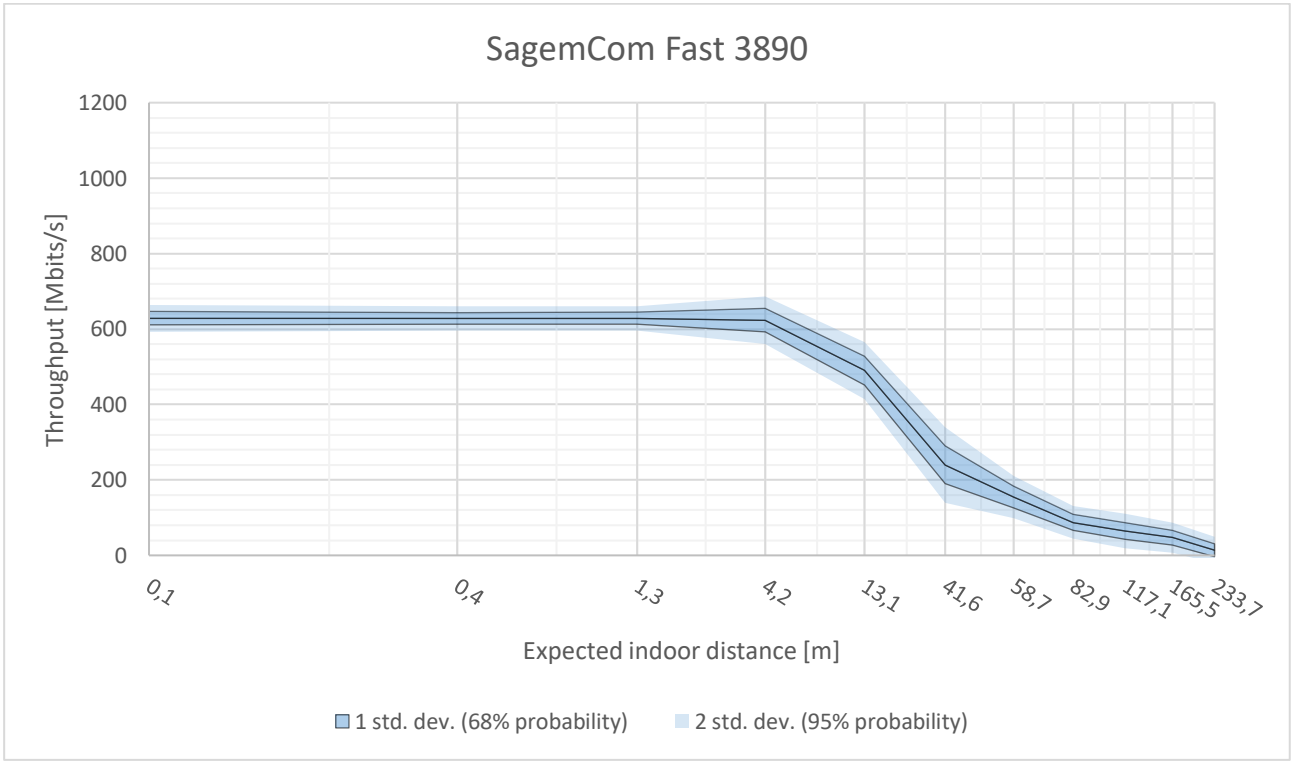
4.2 Kaon DG2200

Model / type	DG2200
Serial no.	071201600057588
Producent	Kaon



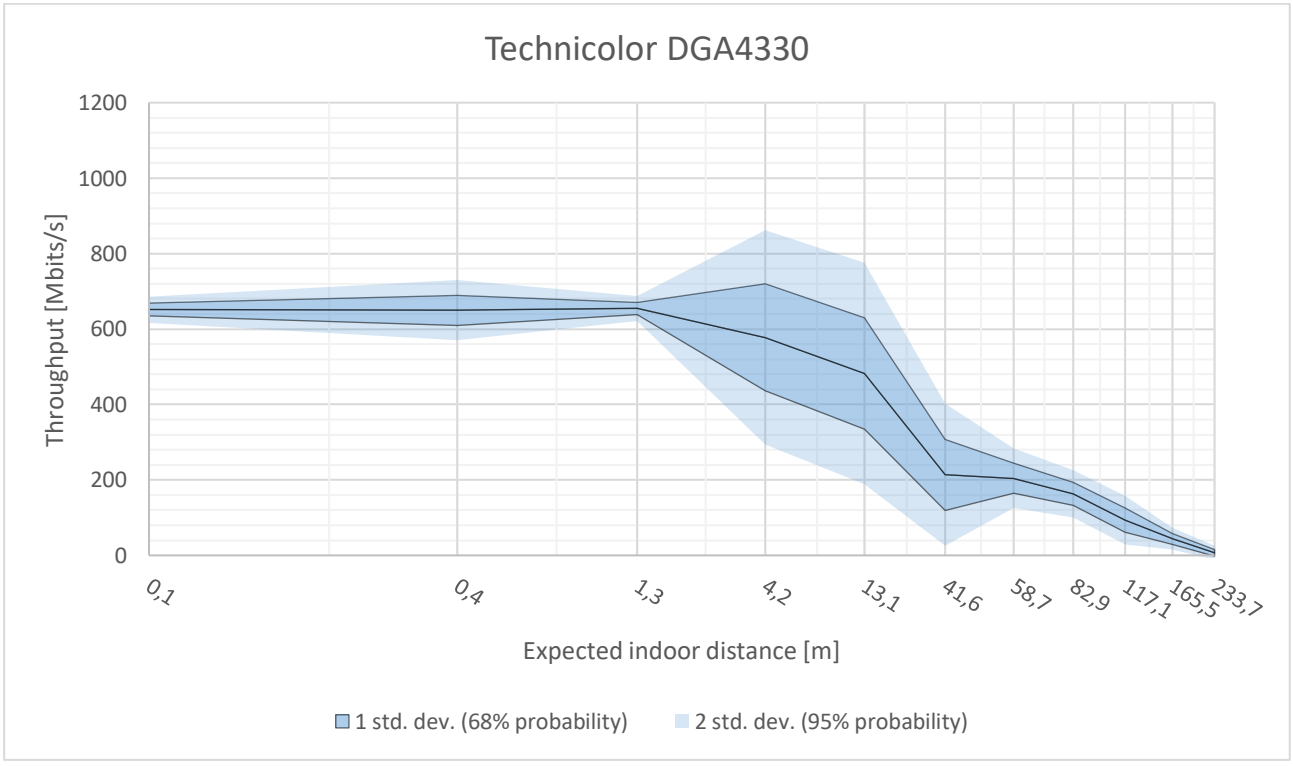
4.3 SagemCom F@st 3890

Model / type	F@st 3890
Serial no.	DM1815618005326
Producent	SagemCom



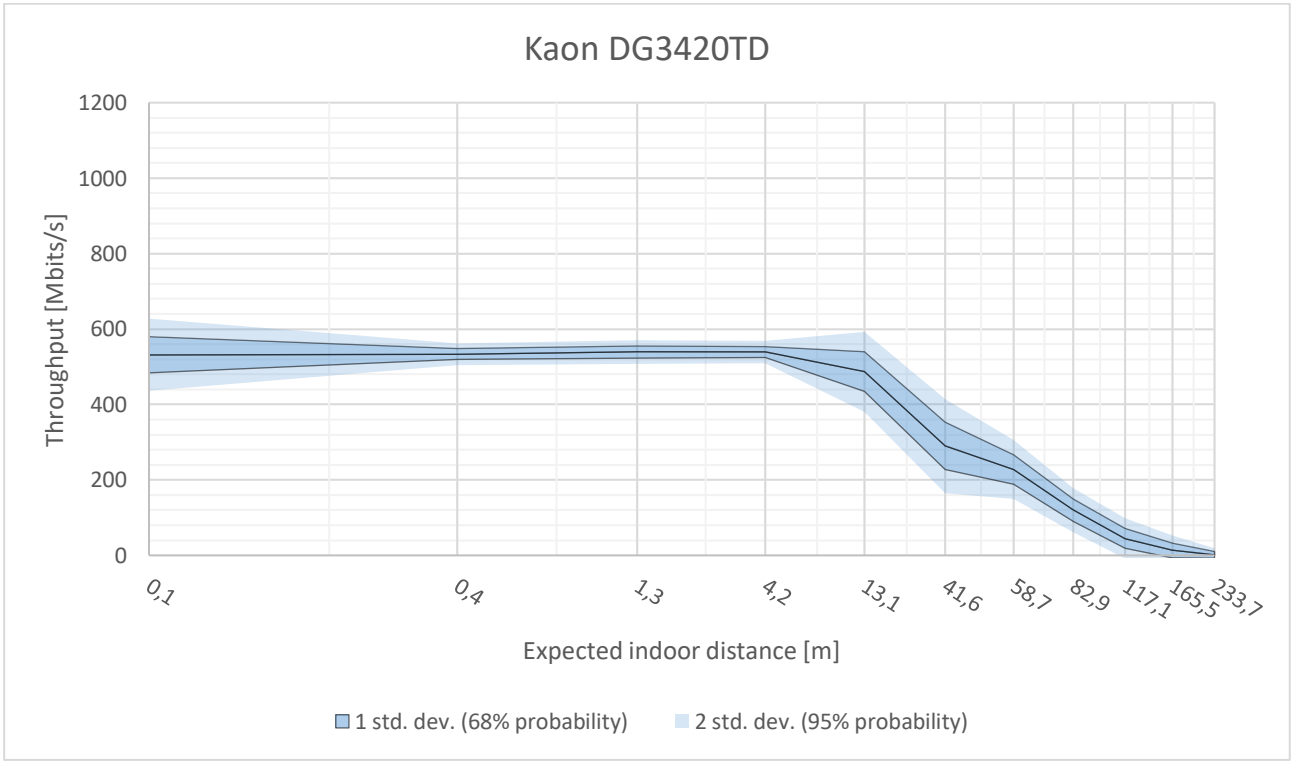
4.4 Technicolor DGA4330

Model / type	DGA4330
Serial no.	CP2007RA6JE
Producent	Technicolor



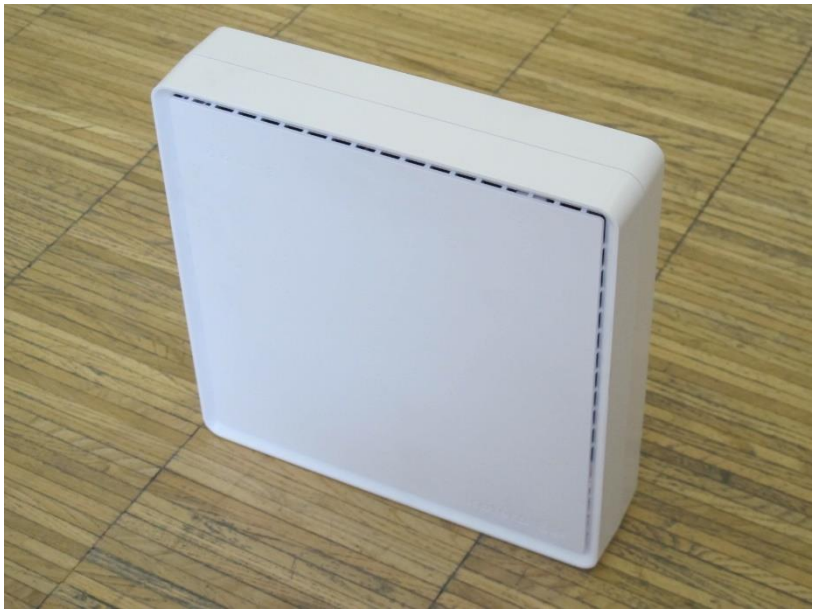
4.5 Kaon DG3420TD

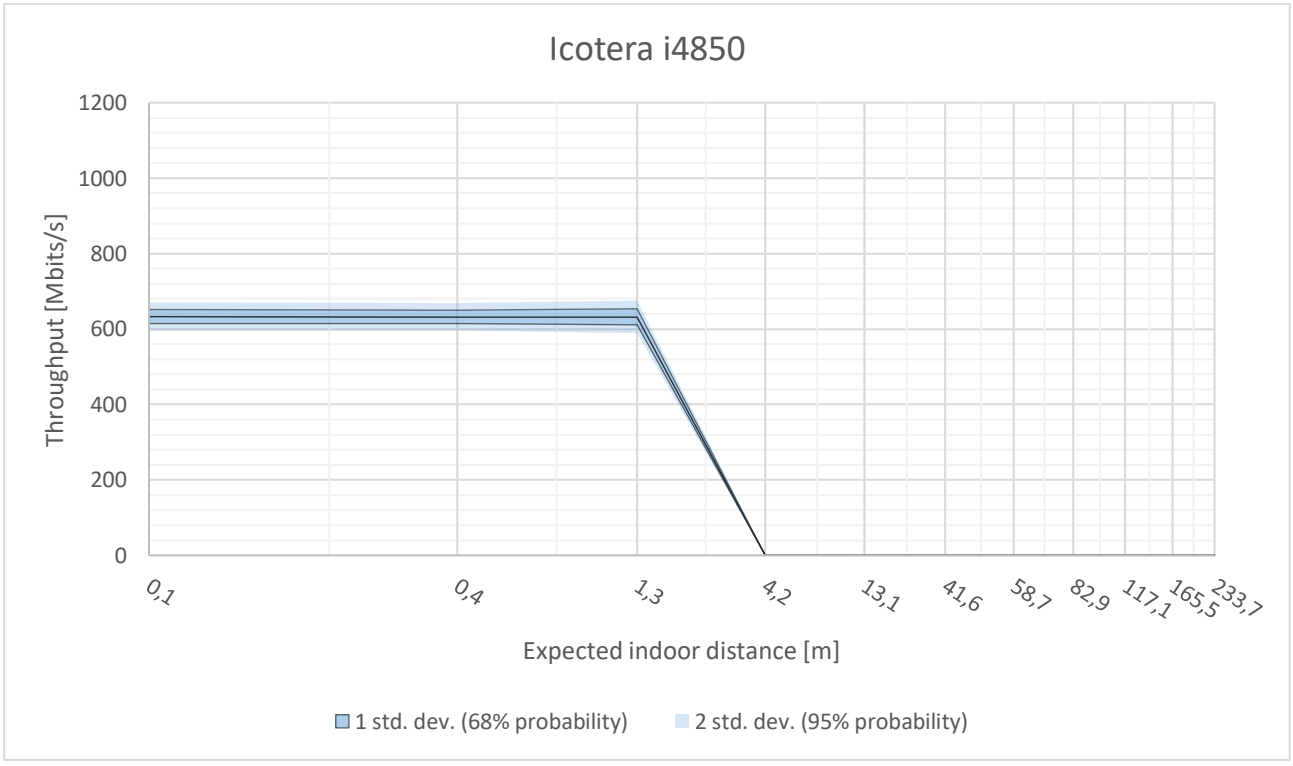
Model / type	DG3420TD
Serial no.	BS10064932001675
Producent	Kaon



4.6 Icotera I4850

Model / type	I4850
Serial no.	S200Y27012989
Producent	Icotera





4.7 Zyxel VMG3925-10A

Model / type	VMG3925-10A
Serial no.	4850002520148099
Producent	Zyxel