

A first Estimation of Spectrum Demand for THz Use Cases

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*21 November 2024 (updated 10
December 2025)*



Scope

- This presentation is intended to provide a first estimation of spectrum demand beyond 100 GHz
- The use cases and model assumption are taken from ETSI ISG THz GR001 on the „Identification of use cases for THz communication systems” [1]

Overview on Uses Cases defined in [1]

- In its GR001 ETSI ISG THz has defined 19 use cases in nine application areas
 - TIMES contributed to the definition of these use cases by providing inputs about potential industrial applications [6]
- For these use cases amongst others peak data rates have been defined, which are the basis for this study
- 18 of these use cases are for data communication.
 - The use case on simultaneous imaging, mapping, and localization is not considered in this study

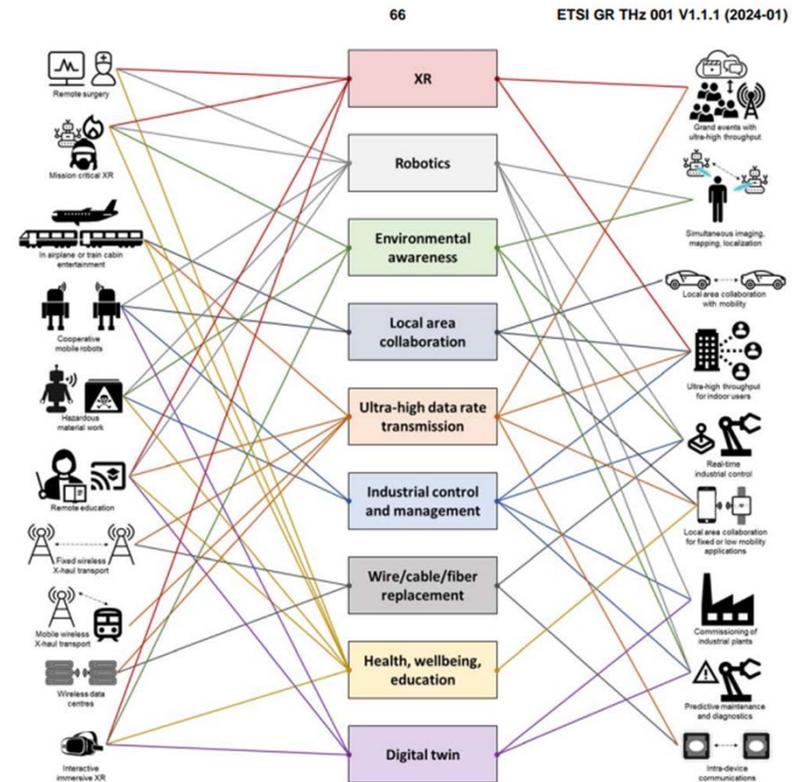


Figure 36: Use case mapping to application areas

[1]

Methodology

- In a first step aggregated data rates are calculated for each of the use cases based on their peak data rates and the number of simultaneous users.
 - For a couple of use cases assumptions have been made based on the number of simultaneous users, which need to have use different frequency (i.e. frequency re-use) in order to mitigate interference. In [3] it has been shown, that even for fixed links in data centers with high gain antennas, interference exists due to a combination of multipath propagation and non-ideal antenna patterns (sidelobes)
 - This effect will be even more significant for mobile applications, where antennas require beamsteering capabilities and lower sidelobe suppression can be expected.
 - More detailed investigations in the future on the frequency re-use might reveal different numbers
- From the aggregated data rates the required spectrum has been calculated assuming a variety of MCS specified in [4]

Data Rates of Use Cases form ETSI ISG THz GR001 (1/2)

Use case	Remarks	Peak Data Rate/Gbps	Assumed number of simultaneous Users	Assumed aggregate Data Rate
Remote Surgery (3D camera flow)	Only a data rate of 20 Gbps is given for the 3D camera flow; other sub-applications have data rates < 1.5 Mbps; number of users for applications not given. Assumption is made that 20 Gbps are for one link	20	1	20
In-Airplane/In-train Communication	GHz bandwidths per user given in [1]; interference between different links might forbid a frequency re-use of 1. Therefore is assumed, that each group of 10 simultaneous users will require separate frequency bands	1	10	10
Cooperative Robots	600 Mbps to 3 Gbps may be required for video processing oof-loading @ link distances less than 100m. Assumption of 10 simultaneous users with separate frequency bands	3	10	30
Hazardous material work	No numbers are given, high-resolution video-stream is mentiond => similar requirements as for cooperative robots	3	10	30
Remote Education (3D holographic display of on-site virtual avatar)	2-4 Tbps are mentioned	2000	1	2000
Remote Education (Interactive avatar robot control)	1 Gbps without compression mentioned Assumption of 10 simultaneous users with separate frequency bands	1	10	10
Fixed Point-to-Point wireless Applications (x-Hauling)	up to 100 Gbps are mentioned	100	1	100
Fixed Point-to-Point wireless Applications (enterprise p-t-p)	up to 20 Gbps for a user experienced data rate up to 100 Mbps	20	1	20
Mobile wireless X-haul transport	up to 20 Gbps for a user experienced data rate up to 100 Mbps; 106 devices per sqm	20	1	20
Data Centers	based on [2] several Gbps up to several 100 Gbps, assuming 4 simultaneous users with separate frequency bands for interference mitigation	100	4	400

Data Rates of Use Cases from ETSI ISG THz GR001 (2/2)

Use case	Remarks	Peak Data Rate/Gbps	Assumed number of simultaneous Users	Assumed aggregate Data Rate
Interactive Immersive XR	at least 1 Gbps per user; no mentioning of user density => assumption made is 10 simultaneous users as for other use cases	1	10	10
Mission critical XR	no numbers given => numbers taken from Interactive/Immersive use case with a larger number of users	1	20	20
Real-time industrial Control	data rate up to 100 Mbps; but many simultaneous users (50 assumed here in this study, potentially short distances allowing antennas with less gain)	0,1	50	5
Commissioning of industrial plants	Peak and average throughput mentioned; numbers of simultaneous users to be considered to avoid interference; same assumption as for data centers	100	4	400
Grant Events with ultra-high throughput	280 Mbps per user and 3500 users per base station streaming; the assumed aggregate data rate is for backhauling rather than for access	0,28	3500	980
Ultra-high throughput for indoor users	up to 1 Gbps throughput with up to 10000 devices per sqkm.; assumption made is 10 simultaneous users as for other use cases	1	10	10
Intra-device communications	from [2]: 40 Gbps	40	1	40
Local Area collaboration for fixed or low mobility applications	no numbers given	100	1	100
Local Area collaboration for vehicular applications	no numbers given	100	1	100
Local Area collaboration for train-to-train scenarios	up to 20 Gbps for a user experiences data rate of up to 100 Mbps	100	1	100
Predictive Maintenance and diagnostics	Peak throughput of 100 Gbps, average throughput of 10 Gbps; 0.5 devices per sqm; for interference reasons 4 devices with independent carrier frequencies assumed	100	4	400

Spectrum Demand for Various MCS

Use case	Spectrum Demand / GHz					
	QPSK 14/15 LDPC	QPSK 11/15 LDPC	16 QAM, 14/15 LDPC	16 QAM, 11/15 LDPC	64 QAM, 14/15 LDPC	64 QAM, 11/15 LDPC
Remote Surgery (3D camera flow)	10,71	13,64	5,36	6,82	3,57	4,55
In-Airplane/In-train Communication	5,36	6,82	2,68	3,41	1,79	2,27
Cooperative Robots	16,07	20,45	8,04	10,23	5,36	6,82
Hazardous material work	16,07	20,45	8,04	10,23	5,36	6,82
Remote Education (3D holographic display of on-site virtual avatar)	1071,43	1363,64	535,71	681,82	357,14	454,55
Remote Education (Inatractive avatar robot control)	5,36	6,82	2,68	3,41	1,79	2,27
Fixed Point-to-Point wireless Applications (x-Hauling)	53,57	68,18	26,79	34,09	17,86	22,73
Fixed Point-to-Point wireless Applications (enterprise p-t-p)	10,71	13,64	5,36	6,82	3,57	4,55
Mobile wireless X-haul transport Data Centers	10,71	13,64	5,36	6,82	3,57	4,55
	214,29	272,73	107,14	136,36	71,43	90,91

Numbers in red: spectrum demand based on assumption of simultaneous users

Spectrum Demand, which fits into the 44 GHz window between 252 and 296 GHz

Use case	Spectrum Demand / GHz					
	QPSK 14/15 LDPC	QPSK 11/15 LDPC	16 QAM, 14/15 LDPC	16 QAM, 11/15 LDPC	64 QAM, 14/15 LDPC	64 QAM, 11/15 LDPC
Interactive Immersive XR	5,36	6,82	2,68	3,41	1,79	2,27
Mission critical XR	10,71	13,64	5,36	6,82	3,57	4,55
Real-time industrial Control	2,68	3,41	1,34	1,70	0,89	1,14
Commissioning of industrial plants	214,29	272,73	107,14	136,36	71,43	90,91
Grant Events with ultra-high throughput	525,00	668,18	262,50	334,09	175,00	222,73
Ultra-high throughput for indoor users	5,36	6,82	2,68	3,41	1,79	2,27
Intra-device communications	21,43	27,27	10,71	13,64	7,14	9,09
Local Area collaboration for fixed or low mobility applications	53,57	68,18	26,79	34,09	17,86	22,73
Local Area collaboration for vehicular applications	53,57	68,18	26,79	34,09	17,86	22,73
Local Area collaboration for train-to-train scenarios	53,57	68,18	26,79	34,09	17,86	22,73
Predictive Maintenance and diagnostics	214,29	272,73	107,14	136,36	71,43	90,91

Situation wrt Standards and Radio Regulations

- Radio Regulations:
 - At WRC 2019 a total of 137 GHz of spectrum between 275 GHz and 450 GHz has been identified for the use by THz communications (this covers MOBILE and FIXED service)
 - At WRC 2023 a preliminary agenda item for WRC 2031 has been defined to allocate spectrum for MOBILE and FIXED service in the spectrum range 275-325 GHz
 - This has to be confirmed at WRC 2027 under the agenda item, which defines the agenda for WRC 2031
- Standards
 - IEEE Std 802.15.3-2023 defines point-point communication systems in the frequency Range 252 to 450 GHz including channel plans with bandwidths between 2.16 Ghz and 69.12 GHz
 - ETSI ISG THz has done a complete spectrum inventory above 100 GHz [7]

Conclusions

- Many use cases have a spectrum demand of 10x GHz up to several hundred GHz
- Such large amounts of spectrum (>15 GHz) are only available beyond 252 GHz [5]
 - Between 252 GHz and 450 GHz a total of 160 GHz has been allocated or at least identified (by footnote 5.564A of the Radio Regulations) for the use by MOBILE and FIXED service (i.e. THz Communications), although the spectrum is fragmented into different sub-bands.
- One of the largest chunks of continuous spectrum (44 GHz) around 300 GHz can be found between 252 and 296 GHz

12 out of 18 investigated use cases fit into the 44 GHz continuous spectrum between 252 and 296 GHz with 16 QAM

References

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- [5] ETSI GR THz 002 V1.1.1 (2024-03), Identification of frequency bands of interest for THz communication systems [Online] https://www.etsi.org/deliver/etsi_gr/THz/001_099/002/01.01.01_60/gr_THz002v010101p.pdf (accessed 17 March 2024)
- [6] TIMES D2.1 - Definition of use cases, KPIs, and scenarios for channel measurements [Online] <https://www.times6g.eu/deliverables/definition-use-cases-kpis-and-scenarios-channel-measurements>
- [7] ETSI GR THz 002 V1.1.1 (2024-03), TeraHertz technology (THz); Identification of frequency bands of interest for THz communication systems, https://www.etsi.org/deliver/etsi_gr/THz/001_099/002/01.01.01_60/gr_THz002v010101p.pdf