Fostering the Innovation Potential of Research Infrastructures

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CLONETS – CLOck NETwork Services
Strategy and innovation for clock services over optical-fibre networks

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User Needs Survey Report
Final

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LIST OF ACRONYMS AND ABBREVIATIONS

CLONETS	CLOck NETwork Services: Strategy and innovation for clock services over optical-fibre networks Project
EC	European Commission
Galileo	Name of the European global navigation satellite system
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
NMI	National Measurement Institute
NREN	National Research and Education Networks
SME	Small and Medium sized Enterprise
RI	Research Infrastructure
TF	Time and Frequency
TOR	Time Of Reply
WP	Work Package

LIST OF PROJECT PARTNER ACRONYMS

AGH / AGH-UST	Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie, Cracow, Poland
CESNET	CESNET, zájmové sdružení právnických osob, Prague, Czech Republic
CNRS*	Centre National de la Recherche Scientifique, Paris, France
INRIM	Istituto Nazionale di Ricerca Metrologica, Turin, Italy
GARR#	Gruppo per l'Armonizzazione delle Reti della Ricerca, Rome, Italy
Menlo	Menlo Systems GmbH, Martinsried, Germany
Muquans	Muquans, Talence, France
NPL	National Physical Laboratory, Teddington, United Kingdom
OBSPARIS¶	Observatoire de Paris, Paris, France
OPTOKON	OPTOKON a.s., Jihlava, Czech Republic
Piktime Systems	Piktime Systems sp z o.o., Poznan, Poland
PSNC	Instytut Chemii Bioorganicznej Polskiej Akademii Nauk – Poznańskie Centrum Superkomputerowo-Sieciowe, Poznan, Poland
PTB	Physikalsch-Technische Bundesanstalt, Braunschweig, Germany
RENATER	Groupement d'interêt Public pour le Reseau National de Telecommunications pour la Technologie, l'Enseignement et la Recherche, Paris, France
SEVENSOLS	Seven Solutions S.L., Granada, Spain
TOP-IX	Consorzio TOrino Piemonte Internet eXchange, Turin, Italy
UCL	University College London, London, United Kingdom
UP13	Université Paris 13, Villetaneuse, France
UPT AV CR (ISI)	Ustav Pristrojove Techniky AV, v.v.i., Brno, Czech Republic

* linked third party to OBSPARIS
# third party to INRIM
¶ coordinator

EXECUTIVE SUMMARY

This deliverable D3.3 is the report on the survey conducted in order to better assess and understand the needs (current and future) of potential end users, beyond National Measurement Institutes (NMIs) and Research Infrastructures (RIs), for the dissemination of optical frequency and time references over a network of optical fibers. The survey addressed several categories of questions, for time reference signals and frequency reference signals:

- Perceived value of such service
- Specifications in terms of accuracy and stability
- Operational features

A wide range of sectors of activity, types of organization and sizes of organization replied, confirming the importance of time and frequency (TF) for various different applications. Among the different types of organizations which answered, the category the most represented are SMEs (about 30%). Given the diversity of the respondents, there was naturally a high degree of variability between the responses.

The replies provided in the needs study have led to the following main conclusions:

- Overall, frequency reference signals are employed more frequently than time reference signals and therefore are considered as slightly more relevant.
- The performance of frequency and time reference signals, respectively, are generally required to be better than:
    - 10^{-11} in relative frequency stability (both short-term and long-term),
    - 1 µs in terms of time jitter and timing accuracy.
- Currently, frequency references are predominately in the MHz range. However, in the future, the optical domain is expected to significantly gain in importance.
- The optical domain for frequency references is already important in the field of *Sensing & Instrumentation*. This rapidly growing technological field is expected to benefit from TF references via optical fiber.
- The large majority of time reference signals require traceability to UTC.

The CLONETS Consortium is consequently led to believe that there is a variety of applications, which could benefit from a TF reference signal over optical fiber. Such a network can provide relative frequency stabilities beyond 10^{-11} and could meet the increasing need for optical reference signals. Additionally, the involvement of the NMIs can guarantee certification for frequency references, and traceability to UTC for time references.

1 INTRODUCTION

Time and frequency (TF) reference signals are essential to a wide range of applications with different requirements on the signal characteristics, quality and performance. The CLONETS Consortium has conducted a survey in order to gain additional insight into the TF needs of users in the industrial, public, research and governmental sectors with the goal of identifying different user categories based on these needs. This report summarizes the information collected through an online survey and describes the characteristics and the perceived value of the TF reference signals for different applications.

2 THE SURVEY

The survey was conducted through an online questionnaire put in place using the standardized web based tool SurveyMonkey. The software was chosen because of its flexibility; it supports several different types of questions (single versus multiple choice, the option to enter free text, etc.) and includes a basic flow control (e.g. allows for conditional jumps within the questionnaire). The questionnaire consists of three main sections, whereby the list of all questions can be found in Annex 1:

1. Relevance of TF reference signals

In the first part of the questionnaire, the relevance of TF reference signals and their benefit to the respondents' activities are established (Q.1-Q.3). The section is then followed by two subsections, containing more detailed questions on the employed frequency and time reference signals, respectively. If applicable[1], the respondents are asked to name the application utilizing the reference signal and specify the corresponding quantitative and qualitative parameters of the signal. In both subsections, the respondent is given the option to enter information on up to 3 different applications.

a. Frequency reference signal (Q.4-Q.10, Q.11-Q.17, Q.18-Q.24 referring to the first, second and third applications named in the questionnaire, respectively)
b. Time reference signal (Q.25[2]-Q.31, Q.32-Q.37, Q.38-Q.43 referring to the first, second and third applications named in the questionnaire, respectively).

2. Connectivity within the organization

This section (Q.44-Q.52) is aimed at the users' existing and planned infrastructure, i.e. number of nodes using the reference signal, network technology, existing backup solutions etc.

3. Company and user profile

In the last section (Q.53-Q.61), the respondent is asked to provide details on the organization they work for, i.e. field of operation, country of operation, size, etc. Additionally, the respondent was asked for their identification and if they were interested in staying informed on the CLONETS project.

All the questions of the questionnaire were voluntary. Additionally, the respondent could remain anonymous if they wished to.

[1] The questionnaire is designed such that a sub-section can be skipped, if it is not relevant, i.e. the respondent does not utilize a frequency and/or time reference signal.
[2] Q.25 and Q.26 are duplicates. There was a mistake in the realization of the questionnaire. From now on, we will simply refer to Q.25, while taking into account both Q.25 & Q.26

3 OVERVIEW OF THE RESPONSES

The needs survey aims at gaining an insight into the TF needs of users beyond National Measurement Institutes (NMIs) and Research Infrastructures (RIs) and at identifying TF service categories for different applications. Consequently, a large variety of organizations in the public, research, governmental and industrial sectors were invited to participate in the survey. The survey was advertised on posters at conferences and published on the project's website. Additionally, the project partners sent e-mail invitations to their relevant contacts. In total, the survey was sent to over 260 organizations mainly, but not exclusively, situated in Europe. Despite the Consortium's effort and an extension of the survey's closing date, the number of responses remained below the Consortium's expectations. In the end, 64 non-empty replies were obtained. Among these valid replies, 30 respondents indicated the name of the organization for which they work, 25 respondents indicated their own name and 17 respondents indicated that they are interested in the results of the survey and in a follow-up from CLONETS (Table 1). The relatively low number of responses and the large spread in applications does not allow for a thorough statistical analysis or quantitative statements. This report provides a summary and overview of the information collected in the survey and where possible attempts to identify trends in the TF needs of the respondents.

General overview	
Total number of replies	109
Number of non-empty replies[3]	64
Number of non-anonymous replies[4]	25
Number of respondents interested in a follow-up[5]	17

Table 1. General overview of the replies to the questionnaire.

The quality of the answers is diverse among the 64 respondents, from a situation where only two questions have been answered to cases where almost all the items have been addressed. Hence, the interpretation of the replies was challenging and the conclusions are only preliminary indicating possible trends.

3.1 Geographical Distribution

Over half of the respondents (33 replies) provided their main country of operation among which 12 also named a secondary country of operation (Q.54; Table 2), 6 a third country of operation, and 5 a fourth country of operation. In 3 cases, the respondent indicated *Europe*, or *worldwide* as a country of operation. These replies are not taken into account, because they are too vague. As anticipated, the respondents are almost exclusively located in Europe coinciding with the main area of activity of the CLONETS Consortium and the focus of the project. Although there are responses from throughout Europe, there is a relatively large number of responses from France and the Czech Republic. This bias presumably has two main causes. Firstly, the National Research and Education Networks (NRENs) in these countries are very active in the field of TF distribution, leading to a greater awareness and support of the topic. Secondly, these countries are also the countries of origin of the task leaders, which have put a lot of effort in the dissemination of the survey.

[3] A non-empty reply is defined as a reply which has at least one question answered and a time of response greater than 1 minute.
[4] In a non-anonymous reply the respondent provides their name (Q.58).
[5] The respondent indicates that they would like to be informed on the progress of CLONETS and provides their e-mail address (Q.59).

Q.54 – What is your country of operation?			
Country	**Number of replies**	**Country**	**Number of replies**
Czech Republic	14	Italy	1
France	8	Spain	1
Slovakia	6	Lithuania	1
Poland	3	Austria	1
Benelux	4	Switzerland	1
Germany	2	Russia	2
China	2	UK	2
USA	2	Hungary	1
Singapore	1	Finland	1

Table 2. Geographical distribution of respondents.

The CLONETS project received answers from a wide range of countries, mainly located in Europe. The geographical distribution is biased by the activity of the CLONETS participants and the focus of the CLONETS project.

3.2 Structure and Sector Activity

37 respondents disclosed more detailed information on their institutions (Q.53, Q.55 & Q.56; Table 3). A wide range of different organizations took part in the survey, with the most responses coming from small and medium enterprises (SMEs). Over 80% of the respondents disclosing their type of organization are a company. The survey is consequently expected to be heavily weighted towards the private sector. Unlike the survey on the TF needs of RIs conducted in parallel by the CLONETS project (see Deliverable D1.1), this TF needs survey has a broader scope and intentionally focused on entities other than RIs. As the two surveys are relatively similar, even if the RIs were re-invited to take part in the survey, it would not be surprising if the willingness to re-respond to a similar TF needs survey within such a short time span is much lower.

Q.53, Q.55 & Q.56 - Who answered the questionnaire.	
Type of structure	**Number of replies**
Large company (> 250 employees)	7
Medium size company (50 – 249 employees)	2
SME (< 49 employees)	19
University, Public research organization or other public institution	9

Table 3. Size and type of the respondents' company/organization.

The responses from industry show that TF reference signals are relevant to this sector.

The questionnaire also asked the respondent to provide their sector of activity (Q.53; Table 4) in form of free text. The responses show that various different types of sectors are concerned with issues related to TF references with the two main sectors being *Sensing & Instrumentation* and *Telecom & IT* (Sections 4.4 and 4.5, respectively).

Q.53 - What industry field does your company/organization operate in?	
Sector of activity	**Number of replies**
Telecom and IT	9
Defense / Space	3
Sensing / instrumentation / manufacturer	12
Research	4
Metrology / calibration	4
Energy	2
Finance	1
Other	2

Table 4. Respondents' sector of activity.

	Large company	Medium company	SME	University, Public research organization or other public institution
Telecom and IT	**3**		**6**	
Defence / Space	**1**		**1**	**1**
Sensing & Instrumentation	**1**	**1**	**8**	**2**
Research				**5**
Metrology / calibration			**3**	**1**
Energy	**2**			
Finance		**1**		
Other			**1**	

Table 5. Segmentation of sector by field of activity.

It appears that TF reference signals are part of many scientific, technical and technological activities, independently of the type of the organization and its size.

4 TF NEEDS

The interest of the respondent in TF reference signals is determined through questions Q.1, Q.4 & Q.25, which ask the respondent to rate the relevance of TF reference signals within their organization and whether they are being utilized. The tables below (Table 6, Table 7, Table 8, Table 9) give an overview of the answers received.

Q.1 - How would you describe the relevance of TF reference signal within your organization?					
	Empty	**Not so relevant**	**Medium relevant**	**Relevant**	**Very relevant**
Frequency reference	16	12	6	14	16
Time reference	17	15	9	9	14

Table 6. Relevance of TF reference signals for the respondents.

Q.1		Time				
		Empty	Not so relevant	Medium relevant	Relevant	Very relevant
Frequency	Empty	15	1	0	0	0
	Not so relevant	1	7	0	0	4
	Medium relevant	1	3	2	0	0
	Relevant	0	3	4	6	1
	Very relevant	0	1	3	3	9

Q.1		Time	
		Not relevant	Relevant
Frequency	Not relevant	24	4
	Relevant	8	28

Table 7. Correlations between the relevance of time reference signals and that of frequency reference signals.[6]

Over 60% of the respondents consider that either time and/or frequency reference signals are relevant within their organization, whereby here an empty answer is considered as rating the reference signal as "not so relevant". We note that while 15 respondents do not answer this first question at all (Q.1; Table 6) and 3 respondents only reply to either the frequency or time part of this question, they still provide answers to other parts of the questionnaire. Amongst these empty answers for Q.1 are respondents, who indicate that they use TF reference signals and furthermore provide detailed information. In these cases, an empty answer to Q.1 was presumably an oversight on behalf of the respondent, since the actual utilization of a TF reference signal implies that it is at least somewhat relevant to their activity.

Among the complete[7] answers for Q.1, over half of the respondents rate time and frequency reference signals as equally relevant (see the diagonal in Table 8). When grouped into two categories "not relevant" and "relevant", relevant time generally implies relevant frequency and *vice versa*, whereby time tends to be considered as slightly less relevant than frequency, as implied by the higher number of replies in the sub-diagonal fields compared to those in the super-diagonal fields.

Q.4 and Q.25 - Are you using a frequency / time reference signal?			
	Empty	**No**	**Yes**
Frequency reference	2	14	48
Time reference	10	21	33

Table 8. Utilization of TF reference signals.

[6] In the table to the right, we sub-sum "medium relevant", "relevant" and "very relevant" replies under the label "relevant", and interpret "not so relevant" or empty replies as "not relevant".
[7] An answer was given to both time and frequency reference signals.

Q.4 and Q.25		Time		
		Empty	No	Yes
Frequency	Empty	2	0	0
	No	0	9	5
	Yes	8	12	28

Q.4 and Q.25		Time	
		Not relevant	Relevant
Frequency	Not relevant	11	5
	Relevant	20	28

Table 9. Correlations between the utilization of time and frequency reference signals.[8]

As mentioned in Section 3, the target group of this survey are TF reference signals users. Therefore it is not unexpected that over 80% of respondents declared that they use a TF reference signal[9] with 75% of the respondents utilizing a frequency reference signal and 50% utilizing a time reference signal. (Q.4 and Q.25; Table 8). Among the confirmed TF users, over half indicate that they use both a time and frequency reference signal, over a third that they use a frequency reference signal only and a little less than 10% that use a time reference signal only (Table 9). This distribution is very similar to the relative relevance rating between time and frequency reference signals (Q.1; Table 7). The overall agreement between the responses to Q.4 and Q.25 with those to Q.1 affirms the link between the utilization of a reference signal and its perceived relevance.

Preliminary conclusion: respondents interested in time reference show interest in frequency, and *vis-versa*. However, there are more respondents interested in frequency reference signals than are interested in time reference signals.

4.1 Perceived value of TF References

In order to gain a better understanding of the interest in TF reference signals, the respondents were asked what value a frequency and time reference brings to their activity (Q.2 and Q.3, respectively; Figure 1). Here, the respondents could choose several answers for each question. 44 respondents provided answers to the perceived values of a both a frequency and time reference signal, 7 responded only to the frequency reference and 2 only to the time reference. For both frequency and time references, the majority of these respondents expect an improvement of the quality of their activity indicating that the main driver for an interest in TF reference signals is an added-on value to an existing activity. The second most chosen valuable characteristics are “improving the efficiency of the activity (internal process)”, “acquire a competitive advantage with respect to other actors” and “comply to a regulation (in place, or coming up)” with an equal number of responses each. Overall, the perceived values for either a frequency or time reference signal are very similar displaying the same trend. The only difference being that slightly less responses were given for time references.

[8] In the table to the right, empty replies are counted as a “No”.
[9] Empty replies are counted as a “No”.

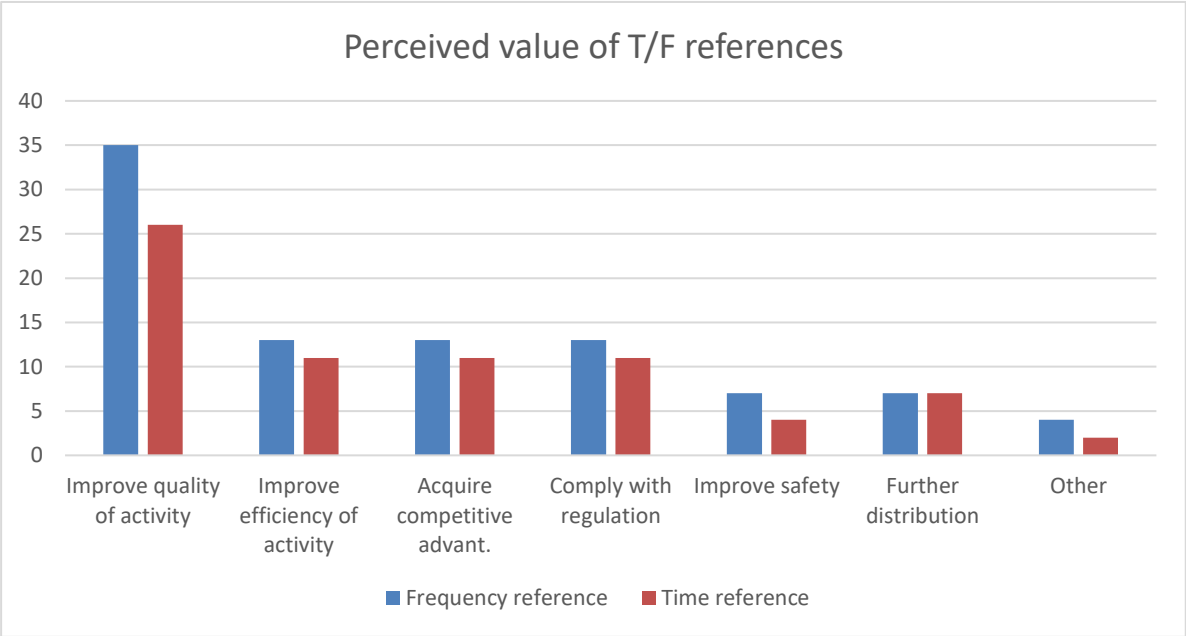


Figure 1. Perceived value of TF references

Preliminary conclusion: the chief driver for an interest in TF reference signals seems to be an added-value to an existing activity followed by three other drivers given an equal importance: improving the efficiency of the activity (internal process), acquiring a competitive advantage with respect to other actors, complying to a regulation (in place, or coming up).

4.2 Performance requirements

4.2.1 Frequency References

The on-line survey tool allowed participants to separately provide details on different frequency references employed for different applications. Most of the respondents providing additional information on their frequency reference signals (33 responses) indicated only one application. 4 of these respondents also provided information on a second application and none provided any information on a third application. This section focuses in more detail on the requirements on the frequency reference signals both qualitatively and quantitatively (Q.6 to Q.10 (first application) and Q.13 to Q.17 (second application)).

In Figure 2, the preferred and expected frequency bands of the employed frequency reference signal are presented. The responses indicate that the frequency range currently used for frequency reference signals is in the radio-frequency range (1-100 MHz). In the future, however, the importance of the optical domain is expected to increase significantly.

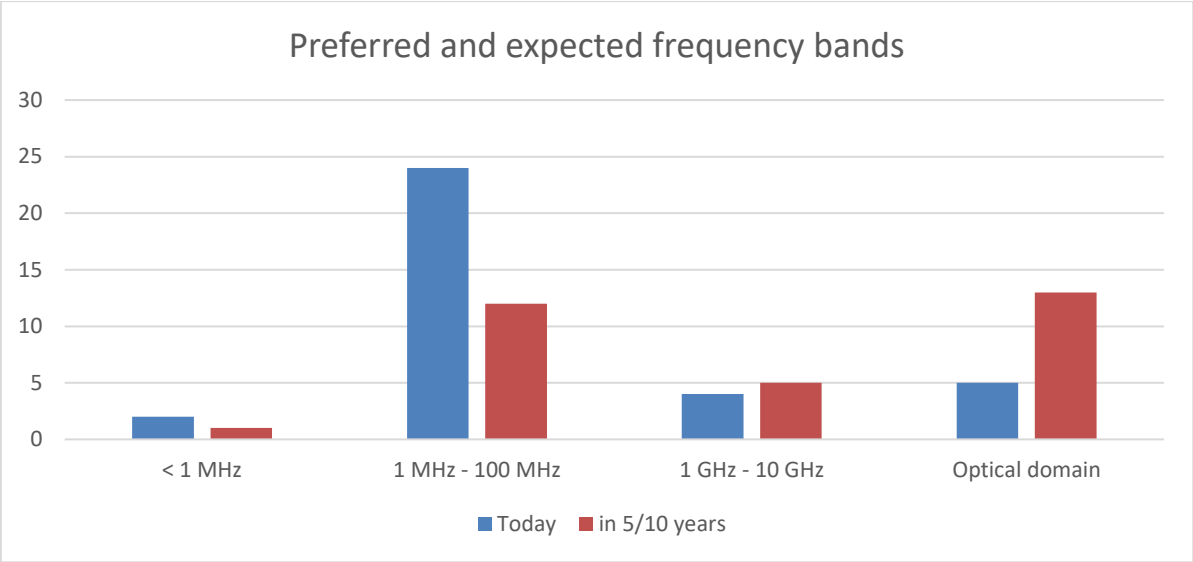


Figure 2. Preferred and expected frequency bands of the employed frequency reference signals.

For approximately half of the applications a certification by an NMI is required indicating that there is a demand for certified frequency references (Q.7 & Q.14; Table 10). With the exception of one reply, all these respondents rate the feature "traceability" as either "critical" (7 responses), "high" (4 responses) or "standard" (5 responses) for the respective application (Figure 4). This highlights that "traceability" and "certification by an NMI" go hand in hand. We note that for none of the applications currently preferring an optical frequency reference signal require a certification by an NMI. However, among the 8 respondents, which currently are not using an optical frequency reference, but which anticipate using an optical frequency reference in the future, half require a certified frequency reference. Consequently, it can be expected that the need for the certification of optical frequency references will increase in the future.

Q.7 & Q.14 - Does the application require a certified frequency reference?	
Certification by an NMI	17
Link to other references (GPS…)	2
No	18

Table 10. Demand for a certification of the frequency reference.

Preliminary conclusion: although optical frequency references are not used in the majority of the cases today, it is believed that they will gain importance in the future together with the need for their certification.

The performance requirements on the frequency references are illustrated in Figure 3 (Q.8 & Q.15). The vast majority of users indicate that they require a relative frequency stability better than 10^{-9} for both short-term and long-term stabilities. Notably, half of the users declare needing frequency references with a relative frequency stabilities beyond 10^{-11}. The questionnaire did not ask about the need for performances beyond this level and therefore the ultimate relative frequency stability required by the respondents is not known.

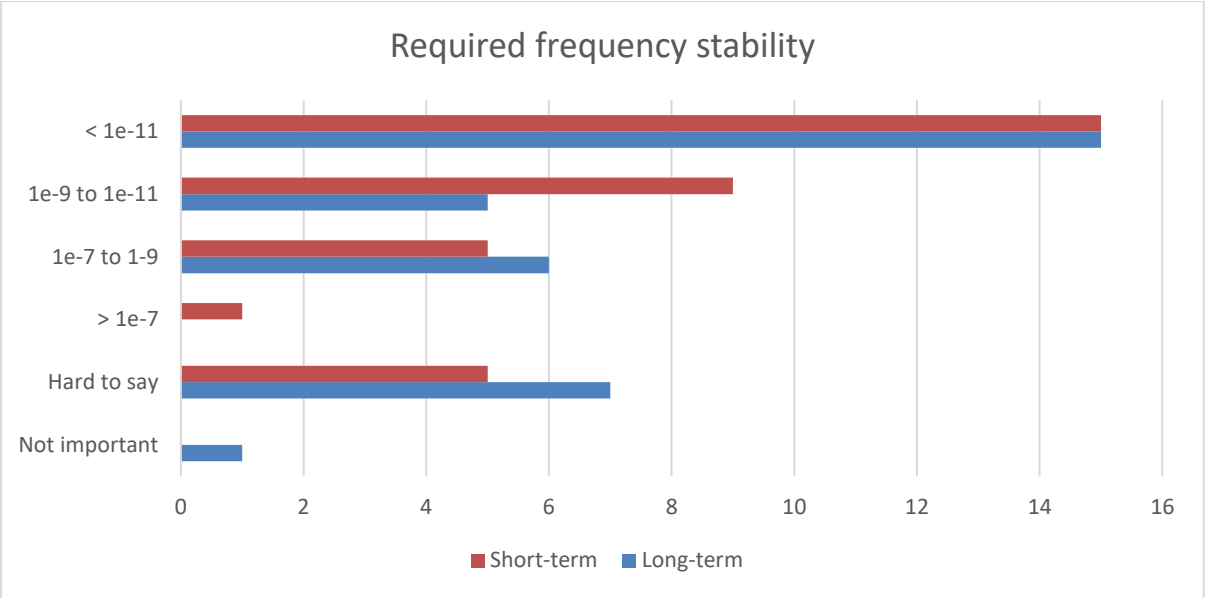


Figure 3. Short- and long-term stability requirement on the frequency reference signal.

Preliminary conclusion: the required level of relative stability for frequency references lies below 10^{-11} for both short-term and long-term fluctuations.

Aside from quantitative specifications, the questionnaire also inquired on the importance of various operational features of frequency references (Q.9 & Q.16; Figure 4). The respondents were asked to rate the following features: “stability”, “accuracy”, “reliability”, “traceability” and “use of back-up”.

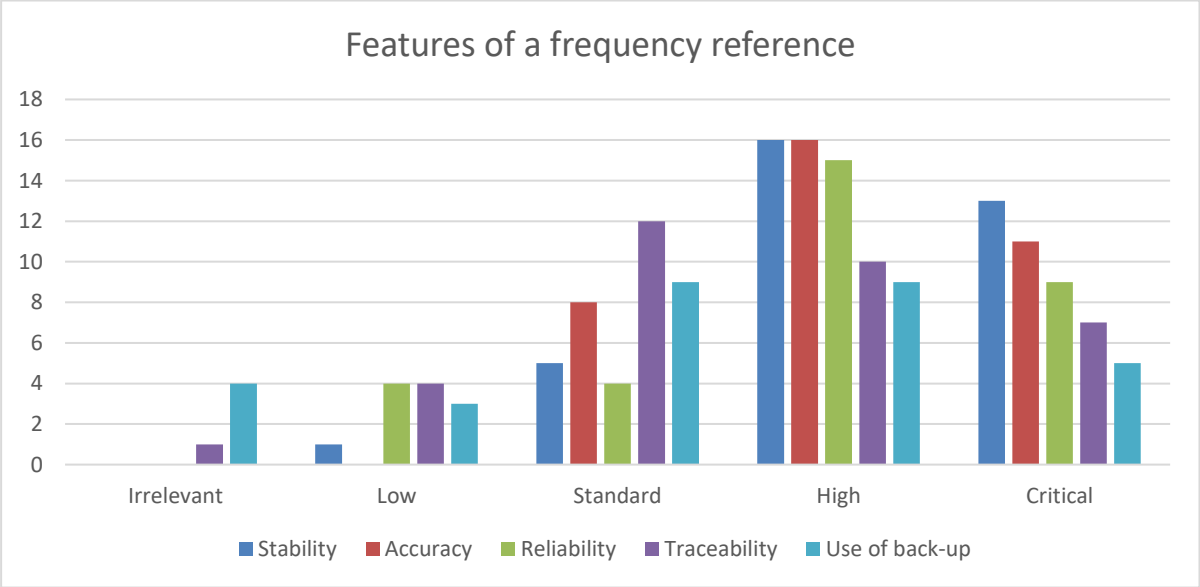


Figure 4. Rating of the operational features of a frequency reference.

Subsuming the replies *high* and *critical* to extract the key parameters, one obtains the following ranking:

(1) Stability: 29
(2) Accuracy: 27
(3) Reliability: 24
(4) Traceability: 17
(5) Use of back-up: 14

The three main features of importance are in the following order “stability”, “accuracy” and “reliability”. While the feature “traceability” is rated less frequently as *critical* or *high* compared to these three key parameters, it still is considered as such by half of the respondents. Additionally, 12 respondents rate “traceability” as *standard*, indicating that it is a somewhat important feature for frequency references.

Short term Stability of a Frequency Reference

Rating of the Stability	Irrelev.	Hard to say	$> e^{-7}$	$e^{-7} - e^{-9}$	$e^{-9} - e^{-11}$	$< e^{-11}$
Irrelev.	0	0	0	0	0	0
Low	0	0	1	0	0	0
Standard	0	1	0	1	2	1
High	0	3	0	4	5	3
Critical	0	0	0	0	2	10

Long term Stability of a Frequency Reference

Rating of the Stability	Irrelev.	Hard to say	$> e^{-7}$	$e^{-7} - e^{-9}$	$e^{-9} - e^{-11}$	$< e^{-11}$
Irrelev.	0	0	0	0	0	0
Low	0	0	0	1	0	0
Standard	0	1	0	3	0	1
High	0	5	0	2	4	4
Critical	1	0	0	0	1	10

Short term Stability of a Frequency Reference

Rating of the Accuracy	Irrelev.	Hard to say	$> e^{-7}$	$e^{-7} - e^{-9}$	$e^{-9} - e^{-11}$	$< e^{-11}$
Irrelev.	0	0	0	0	0	0
Low	0	0	0	0	0	0
Standard	0	1	1	1	3	2
High	0	3	0	4	4	4
Critical	0	0	0	0	2	8

Long term Stability of a Frequency Reference

Rating of the Accuracy	Irrelev.	Hard to say	$> e^{-7}$	$e^{-7} - e^{-9}$	$e^{-9} - e^{-11}$	$< e^{-11}$
Irrelev.	0	0	0	0	0	0
Low	0	0	0	0	0	0
Standard	0	1	0	4	0	3
High	1	4	0	2	3	5
Critical	0	1	0	0	2	7

Table 11. Correlations between the stability requirements and the perceived values of stability and accuracy for frequency references.

Preliminary conclusion: the three main features of a frequency reference that are required are:
(1) Stability
(2) Accuracy
(3) Reliability
This is expressed regardless of the frequency range and the origin of the frequency reference signal.

Regarding the origin of the frequency reference (Q.10 & Q.17; Table 12), 31 respondents provided an answer with 4 also giving an answer for a second application. The question allowed the respondents to choose both internal production and importation as a source of origin, which was the case for 8 applications. This could potentially be interpreted as information on the redundancy of the frequency reference signal.

Q.10 & Q.17 - What is the origin of the frequency reference signal you use?	
Internal production (total)	21
Importation (total)	24

Table 12. Origin of the employed frequency reference.

Q.10 - What is the origin of the frequency reference signal you use? (first application only)?	
Internal production (only)	12
Importation (only)	12
Both internal production and importation	7

Table 13. Origin of the frequency reference; first application only.

The number of respondents declaring that they produce the frequency reference internally is equivalent to those declaring that they rely on a disseminated frequency reference. The use of imported frequency references is relatively common.

4.2.2 Time References

This section focuses on requirements placed on time reference signals (i.e. replies to Q.28 to Q.31 (first application) and to Q.34 to Q.37 (second application)). Again, respondents could provide information on up to three applications. However, only one of the 20 respondents providing more detailed information on their time reference also provided information for a second application.

In Figure 5, the performance specifications for the stability and accuracy of the time reference signal are presented (Q.28 & Q.34). The results indicate that a jitter below 1 µs and an accuracy of 1 ns or better are required.

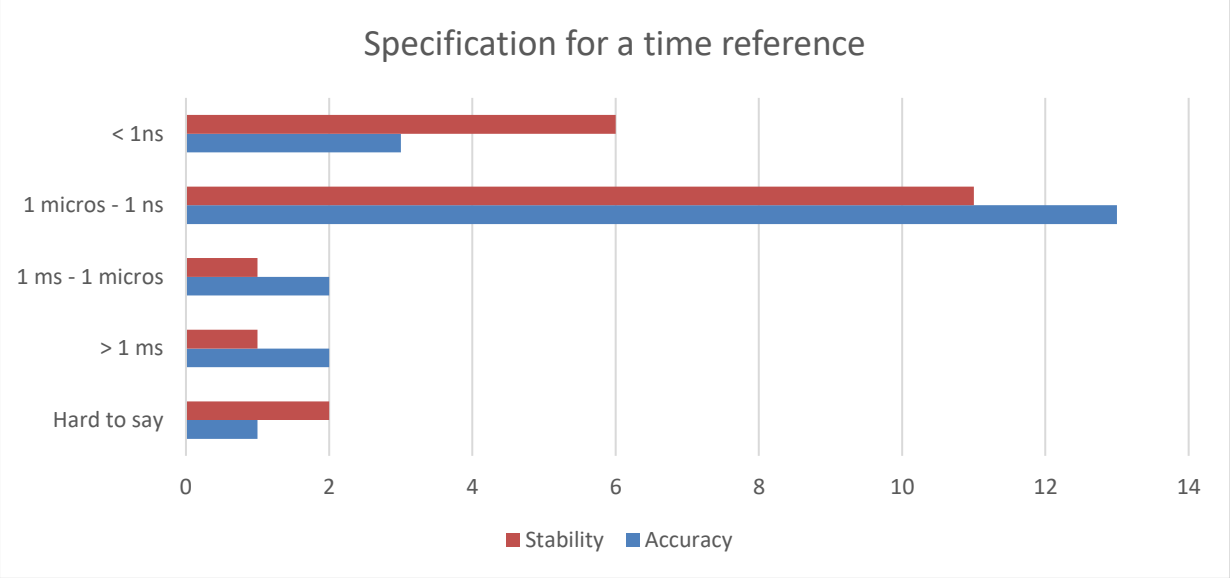


Figure 5. Performance specifications for time reference signals.

Preliminary conclusions: the majority of the respondents declare that their requirements for a timing reference signal are:
- Stability: better than 1 µs
- Accuracy: better than 1 µs

The questionnaire also asked whether the application required legal time (Q.29 & Q.35; Table 14) and UTC traceability (Q.30 & Q.36; Table 15). A third of the respondents using time reference signals indicate that their application requires legal time and two thirds require UTC traceability. This suggests that there is a need for legal time and that UTC traceability is an important feature of time reference signals. All the applications requiring legal time also require UTC traceability. This is not surprising as legal time is often defined by a realization of UTC, although the exact definition of legal time can vary from country to country and is not always linked to UTC. The requirement of UTC traceability does not necessarily imply a need for legal time. In fact, only half of the applications requiring UTC traceability also indicate that they require legal time. However, as expected, the applications not requiring UTC traceability likewise do not require legal time. Consequently, legal time can be considered as an additional feature on top of UTC traceability, even though they often are closely related.

Q.29 & Q.35 - Does the application require legal time?	
Yes	7
No	14

Table 14. Demand for legal time.

Q.30 & Q.36 - Does the application require UTC traceability?	
Yes	14
No	7

Table 15. Requirement for UTC traceability.

Preliminary conclusions:
- If legal time is required, so is UTC traceability.
- UTC traceability does not necessarily require legal time.
- If UTC traceability is not required neither is legal time.

The question asking for the origin of the time reference signal allowed the respondents to choose both internal production and importation (Q.31 & Q.37; Table 16), which was done for 6 applications. As for frequency reference signals, this could be interpreted as information on the redundancy of the reference signal. While for the frequency references half of the signals are produced internally and half are imported, for time references the large majority of signals are imported.

Q.31 & Q.37 - What is the origin of the time reference signal that is used?	
Internal production (total)	9
Importation (total)	19

Table 16. Origin of the time reference signal.

Q.31 - What is the origin of the time reference signal you use (first application only)?	
Internal production (only)	3
Importation (only)	12
Both internal production and importation	5

Table 17. Origin of the time reference signal; first application only.

The number of respondents declaring that they import their timing reference largely exceed those that produce their time reference internally.

4.3 Connectivity

This section focuses on the connectivity of the TF reference signals, i.e. the optical technology employed, the number of nodes, the distance between nodes and the tolerance to failures. Regarding the optical connectivity and the potential technology employed, 19 respondents provided an answer (Q.44; Table 18). The respondents had the opportunity to select multiple answers including the option to enter free text under "Other". 19 respondents provided an answer to this question with 9 respondents naming only a single technology. The answers show a uniform distribution of optical connectivity solutions. We note that one respondent commented that the cost will be one of the main drivers for further connectivity and another stated that their preferred solution was not available with their market data provider.

Q.44 - In case optical connectivity is relevant for you, what is the available (or foreseen) technology or infrastructure used for your time and frequency applications?	
Dark fiber	9
Network with reserved channel (DWDM)	8
Proprietary optical network	6
Data service above an optical layer	7

Table 18. Technology employed in case of optical connectivity.

Questions Q.45 to Q.47 asked for more information on the TF network of the respondents, whereby respondents could provide multiple answers for the type of node (Q.45; Table 19). The 6 respondents which state that they only have one node all specify "Laboratory" as their only type of node (Q.46.a, Table 20). These respondents either do not provide a range between nodes (4 responses) or state that the range is "below 1 km" (2 responses), the latter of which could be interpreted as seeing the laboratory as the range of distribution. For the most part, the respondents tend to have 10 or less TF nodes (Q.46.a, Table 20). The relatively uniform distribution in the distance between nodes (Q.46.b & Q.47; Table 21) shows that there is no typical range in terms of connectivity for TF reference signals among the respondents, which could be expected given the variety of types and sizes of companies and institutes represented.

Q.45 - Please specify the type of node (separate locations), at which a time and/or frequency reference signal is required.	
Laboratory	14
Devices, instruments, vehicles	8
IoT sensors	3
Other	3

Table 19. Type of nodes for TF reference signals.

Q.46.a - Please specify the approximate number of nodes (separate locations) where a time and/or frequency reference signal is required	
1 node	6
Between 2 and 10 nodes	7
Between 11 and 100 nodes	3
Between 101 and 1000 nodes	1

Table 20. Number of nodes requiring a TF reference signal.

Q.46.b & Q.47 - Please specify the approximate range between nodes (separate locations) where a time and/or frequency reference signal is required.	
Below 1 km	4
1 km to 10 km	3
10 km to 100 km	3
100 km to 1000 km	2
> 1000 km	3

Table 21. Approximate distance between nodes.

The following questions (Q.48 to Q.51) address the issue of failures in receiving the TF reference signal. Among the respondents approximately a fourth have experienced a failure (Q.48; Table 22). All of these respondents (5 responses) replied that their organization has put in place redundancy features in case of failures. It is not clear whether the failures prompted this or whether the failures occurred despite the redundancy features put in place. Three of these respondents also provided information on the re-occurrence of the interruption. They state that failures occur once per year or less. The acceptable time of interruption for the TF reference signals varies among the respondents and is most likely dependent on the application. We note that Question Q.49 (Table 23) was an open ended question and was answered by only 9 of the 19 respondents, which replied to the whether or not their company has experienced any failures. It is possible that this information is not well known among the respondents.

Q.48 - Have any failures related to the reception of the time and/or frequency signal occurred at your company/organization in the past?	
Yes	5
No	14

Table 22. Occurrence of failures to receive the TF reference signal.

Q.49 - What is an acceptable duration of interrupted access to the time and/or frequency reference signal at your company/organization?	
Not acceptable	1
10 minutes	1
1 hour or less	2
1 day or less	2
1 week	3

Table 23. Acceptable duration of an interruption.

Approximately a third of the respondents answering the question on whether redundancy procedures have been put in place (Q.50; Table 24) answered positively. Not surprisingly, the respondents using a frequency reference signal and which have a redundancy procedure in place

all rate *resiliency* as either "critical" or "high" for a frequency reference. The large majority of the respondents also test their redundancy procedures (Q.51; Table 25).

Q.50 - Has your company/organization applied any redundancy procedures for failures related to the reception of a time and/or frequency reference signal?	
Yes	13
No	7

Table 24. Application of redundancy procedure against the failure to receive the TF reference signal.

Q.51 - Has your company/organization tested any redundancy procedures for failures related to the reception of a time and/or frequency reference signal?	
Yes	11
No	9

Table 25. Testing of the redundancy procedures put in place.

The number of TF reference nodes and distance between nodes varies among the respondents.
The majority of the respondents has put into place redundancy procedure for the reception of TF reference signals.

4.4 Specific focus on a user category: Sensing & Instrumentation

We briefly review the responses from users in *Sensing & Instrumentation* (12 replies in total). In this field, frequency references are used more frequently than time reference signals (Q.4 & Q.25; Table 27). As expected they are overall also considered as more relevant (Q.1; Table 26). With the exception of one respondent, all respondents in this field use a frequency reference. The respondent that stated that they neither use a frequency nor time reference signal rated the relevance of a frequency and time reference signal as "medium relevant" and "not so relevant", respectively and did not consider TF references as valuable. Over half of the respondents employing a frequency reference additionally use a time reference signal. None of the respondents use a time reference signal only. One respondent gave information on two different applications.

Q.1 – How would you describe the relevance of TF reference signal within your organization?					
	Empty	**Not so relevant**	**Medium relevant**	**Relevant**	**Very relevant**
Frequency reference	0	2	3	3	4
Time reference	2	5	3	1	1

Table 26. Assessment of the interest in TF issues of the respondents in *Sensing & Instrumentation*.

Q.4 and Q.25 - Are you using a TF reference signal?		
Number of replies	**No**	**Yes**
Frequency	1	11
Time	6	6

Table 27. Utilization of TF reference signals in *Sensing & Instrumentation*.

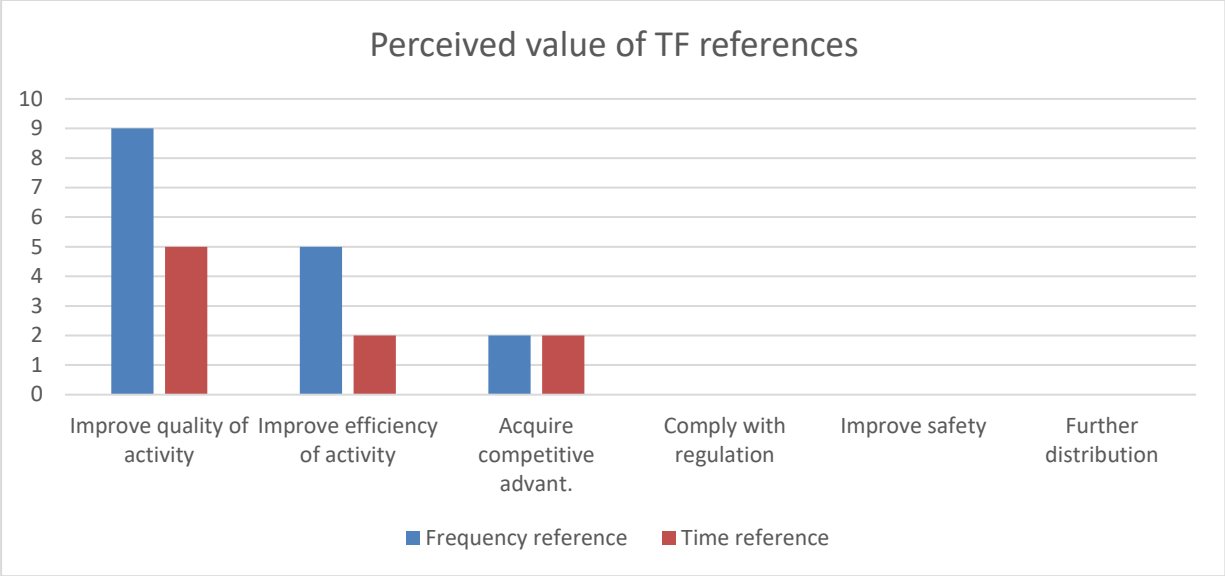


Figure 6. Perceived value of TF references in the field of *Sensing & Instrumentation*.

As in the global survey, the large majority of the respondents expect TF references to improve the quality of their activity (Figure 6). However, the improvement of efficiency appears to comparatively play a more significant role in *Sensing & Instrumentation*.
We note that the preferred frequency band is more strongly weighted towards the optical domain compared to other applications (Q.6 & Q.13; Figure 7). Of the 5 applications working with frequency references in the optical domain today, 3 are in the field of *Sensing & Instrumentation*.

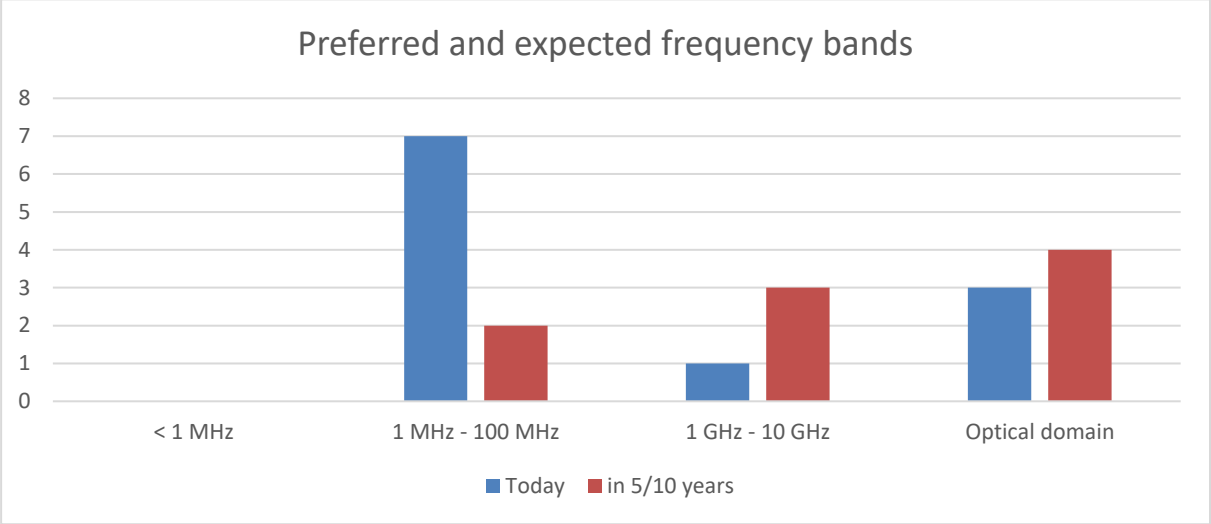


Figure 7. Preferred and expected frequency bands of the employed frequency reference signals in the field of *Sensing & Instrumentation*.

Q.7 & Q.14 - Does the application require a certified frequency reference?	
Certification by an NMI	5
Link to other references (GPS…)	0
No	7

Table 28. Demand for a certification of the frequency reference in the area of *Sensing & Instrumentation*.

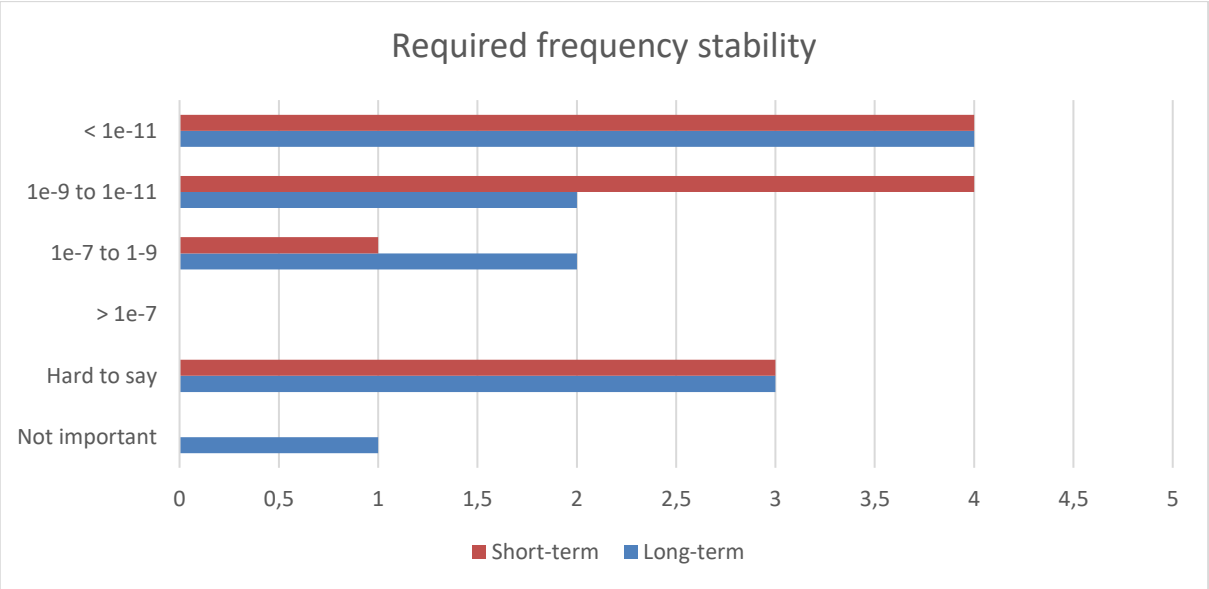


Figure 8. Short- and long-term stability requirement on the frequency reference signal in *Sensing & Instrumentation*.

For the applications in *Sensing & Instrumentation*, it appears that the requirements on the stability of the frequency reference are overall less stringent compared to the global survey or at least not well known (Q.8 & Q.15; Figure 8). A frequency stability better than 10^{-11} is required by only a third of the application in the field of *Sensing & Instrumentation*, whereby over half of all the other respondents declare that their applications require frequency performances beyond this level. However, a fourth of the respondents reply that they do not know the required frequency stability.

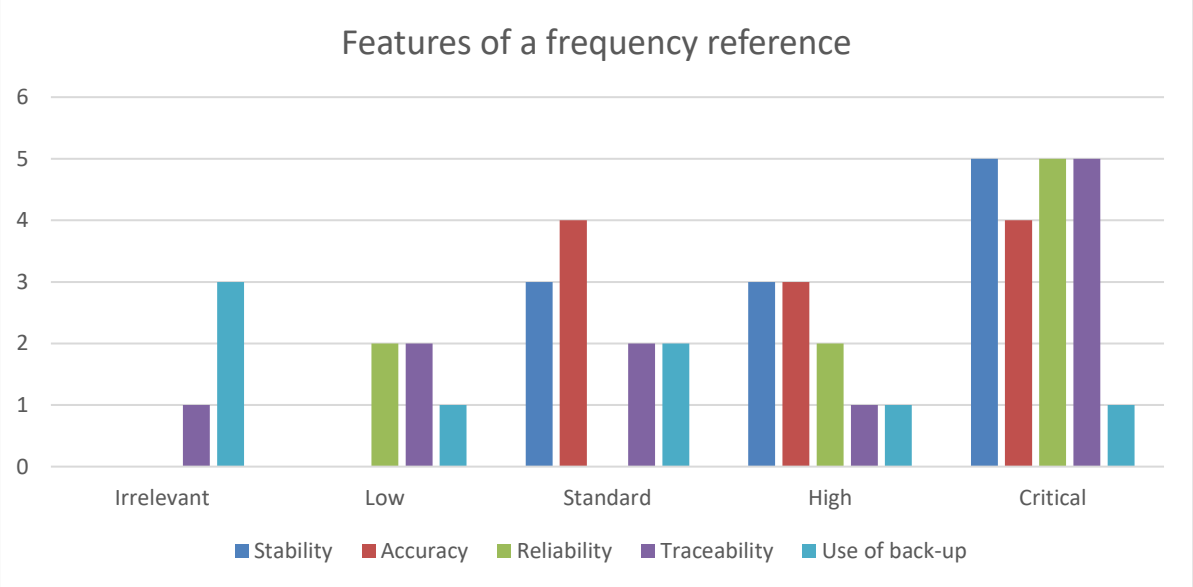


Figure 9. Rating of the operational features of a frequency reference in the field of *Sensing & Instrumentation*.

Figure 9 shows the rating of various features for a frequency reference (Q.9 & Q.&15). If we subsum *high* and *critical*, the given features are ranked in the following manner:

(1) Stability: 8
(2) Reliability: 7
(2) Accuracy: 7
(4) Traceability: 6
(5) Use of back-up: 2

The top three features (stability, accuracy and reliability) are the same as in the global survey. However, traceability comparatively seems to have more importance within the field of *Sensing & Instrumentation*. This feature received almost as many *high* and *critical* scores as the top three features. Among these 6 applications, for which traceability is considered as a feature of *high* or *critical* importance, 5 require a certification by an NMI. The use of a frequency reference as a back-up seems to be rather irrelevant for applications in this field.

Q.10 & Q.17 - What is the origin of the frequency reference signal you use?	
Internal production (total)	7
Importation (total)	5

Table 29. Origin of the employed frequency reference in the field of Sensing and Instrumentation.

In the field of *Sensing & Instrumentation*, most applications rely on either an internally produced frequency reference or an imported one. Only one respondent indicated they use both. There is no clear majority towards either approach.

4.4.1 Comments on Optical Sensing

In the course of project, several direct discussions occurred with potential end-users active in the area of optical sensing. Even though the questionnaire was not able to precisely analyze the impact of a service providing an optical frequency reference at the end of an optical fiber, we highlight some of the insights that have been gained as a result of these discussions. The field of optical sensing has been increasing significantly over the past years, in particular due to continued advances in photonics related technology. It appears that the delivery of an optical frequency reference over optical fibers could be a key enabler for the further development of this field. Its relevance is supported by the following elements:

- The light source (often a laser) represents a significant part of the cost of the optical sensing devices.
- The popularity of optical fiber sensing is rapidly growing and is providing sensors of various different physical quantities (i.e. strain, temperature, pressure, displacement). One particular popular set-up is distributed acoustic sensing, which is commercialized by several companies. Another noteworthy application that has emerged is the use of optical fibers for seismology studies, either on-shore or off-shore. (See for example: Marra, et al. “Ultrastable laser interferometry for earthquake detection with terrestrial and submarine cables”, Science, 360, 6395.)

The specific area of optical sensing is an emerging and rapidly developing application, which is anticipated to benefit from an optical frequency reference provided over fibers.

4.5 Specific focus on a user category: Telecom & IT

We briefly review the responses from users in the field of *Telecom & IT* (9 replies in total). Among these respondents, 3 indicate that they use both a frequency and a time reference signal and correspondingly rate their relevance as either high or very relevant (Q.4 & Q.25; Table 31 and Q.1; Table 30) 3 of the respondents in the *Telecom & IT* sector, state that they use neither a frequency nor time reference signal. As expected, they consider TF reference signals to be not so relevant within their organization.

Q.1 – How would you describe the relevance of TF reference signal within your organization?					
	Empty	**Not so relevant**	**Medium relevant**	**Relevant**	**Very relevant**
Frequency reference	0	3	2	2	2
Time reference	0	4	1	3	1

Table 30. Interest of the surveyed users in the *Telecom & IT* domain in TF issues.

Q.4 and Q.25 - Are you using a TF reference signal		
Number of replies	**Yes**	**No**
Frequency	5	4
Time	4	5

Table 31. Utilization of TF reference signals in Telecom & IT.

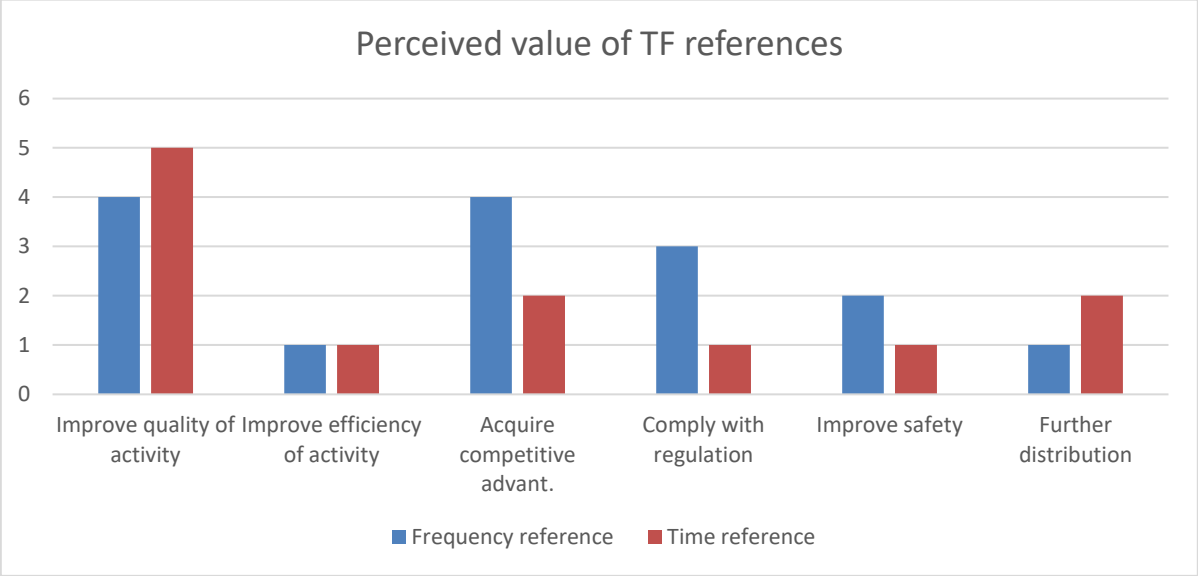


Figure 10. Perceived value of TF references in the *Telecom & IT* sector.

In *Telecom & IT*, the perceived value of TF references seems to differ from that in *Sensing & Instrumentation* (Q.2 & Q.3; Figure 10). Most notably, compliance with regulation, safety and further distribution are considered to be of importance by some of the respondents. However, we note that total number of respondents is low with a third not using a TF reference signal. Therefore a definite statement cannot be made at this stage.

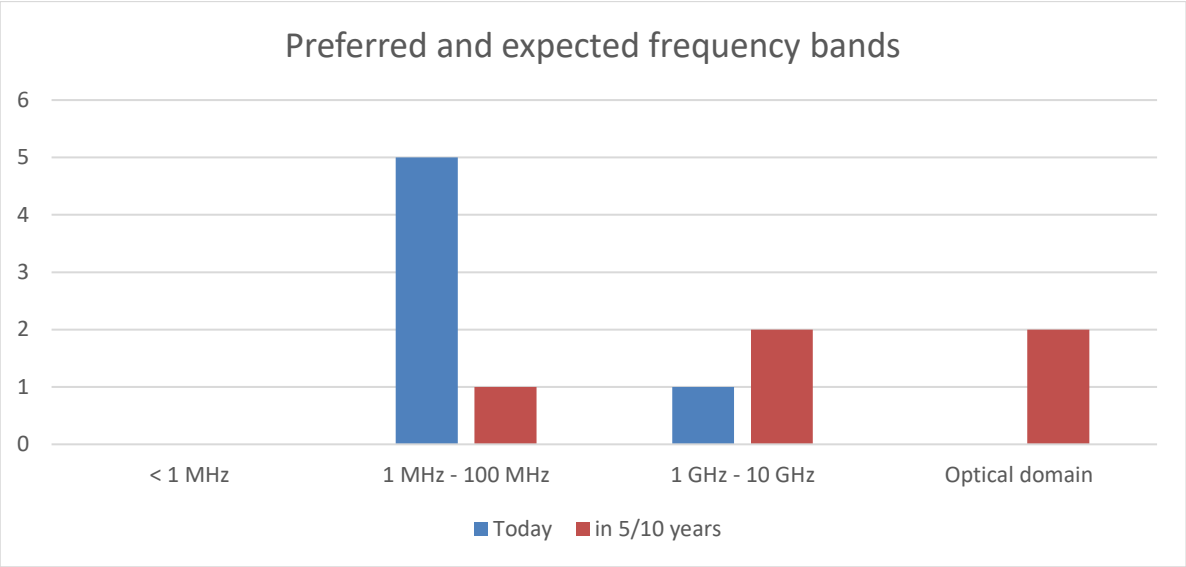


Figure 11. Preferred and expected frequency bands of the employed frequency reference signals by the *Telecom & IT* sector.

Q.7 & Q.14 - Does the application require a certified frequency reference?	
Certification by an NMI	1
Link to other references (GPS…)	0
No	5

Table 32. Demand for a certification of the frequency reference in the area of *Telecom & IT*.

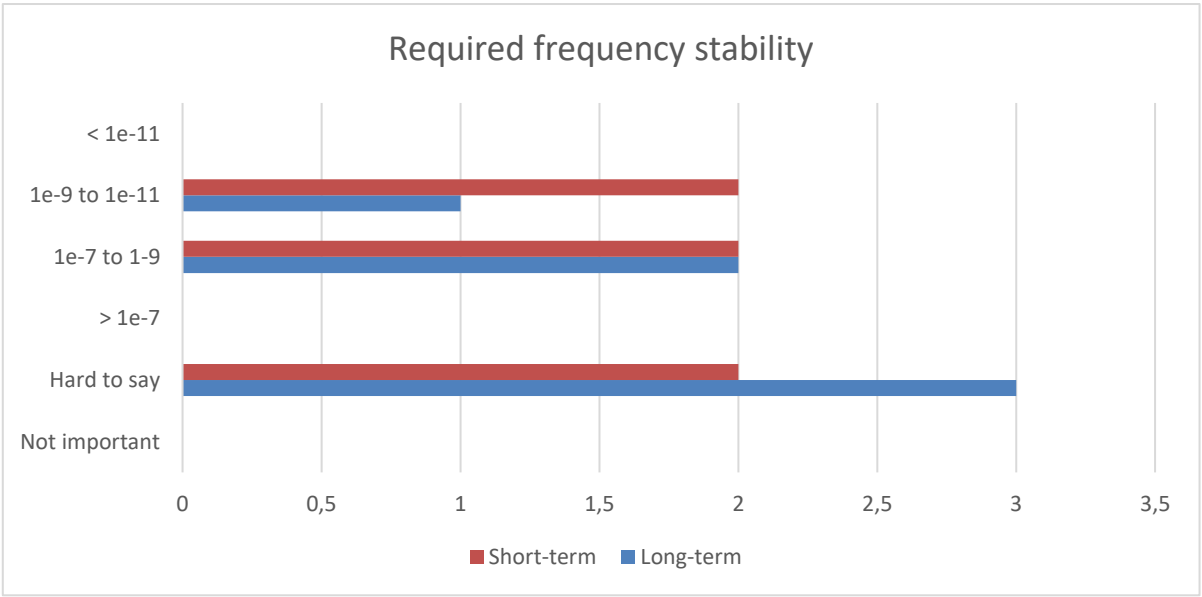


Figure 12. Short- and long-term stability requirement on the frequency reference signal in *Telecom & IT*.

Regarding the stability requirements, there were 3 empty replies corresponding to the respondents not using a TF reference signal. In *Telecom & IT*, it appears that the requirement for the performances is even less stringent than in the global survey (Q.8 & Q.15; Figure 12). Indeed, no one required a frequency stability better than 10^{-11}. The number of *hard to say* responses indicates that a significant proportion of the respondents might not fully understand the issues at stake and suggests that there is a need for educating users.

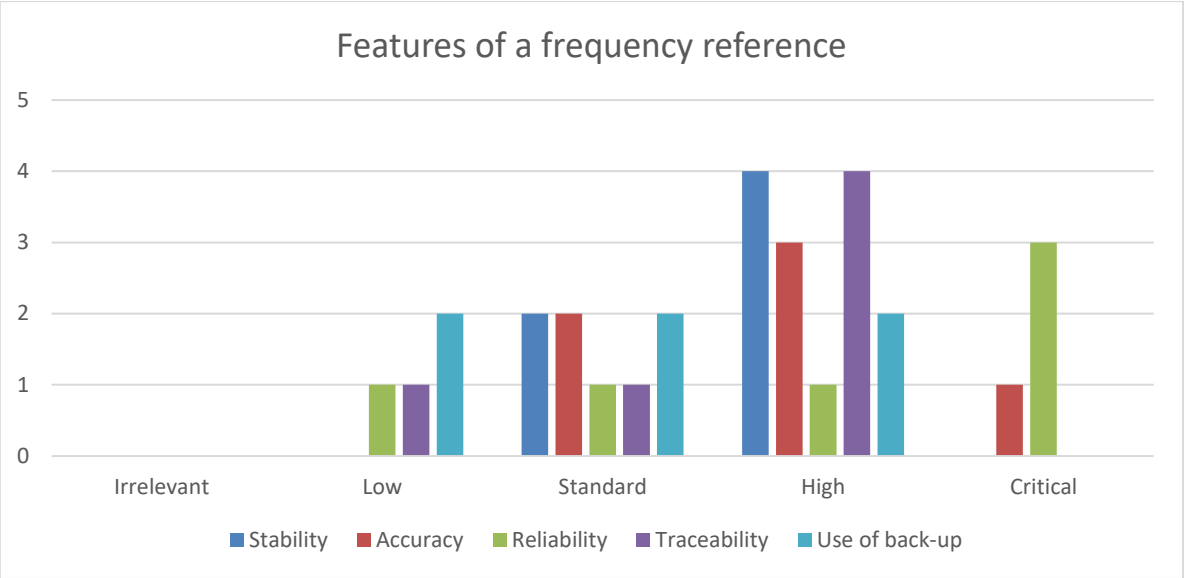


Figure 13. Rating of the operational features of a frequency reference in the field of Telecom & IT.

Figure 13 shows the rating of various features for a frequency reference (Q.9 & Q.15). If we subsum *high* and *critical* here are the scores collected by each features:

- Reliability: 4
- Accuracy: 4
- Stability: 4
- Traceability: 4
- Use of back-up: 2

Given the small number of responses, it is difficult to make any definite statements. We just note that reliability seems to play a slightly more important role in *Telecom & IT* compared to the global survey, in which accuracy and stability were rated as *critical* more often than reliability.

Q.10 & Q.17 - What is the origin of the frequency reference signal you use?	
Internal production (total)	5
Importation (total)	4

Table 33. Origin of the employed frequency reference in the field of Telecom & IT.

Regarding the origin of the frequency reference (Q.10 & Q.17; Table 33), there is no clear majority for either internal production or importation. 2 respondents replied that they utilize both approaches.

5 A SEPARATE TF NEEDS STUDY

On May 24th, 2018, OPTOKON in cooperation with CESNET organized a seminar titled "Secure delivery of sharp time". More than 420 invitations were sent out to:

- 47 representatives of academies, universities
- 15 representatives of experts associations
- 217 representatives of central and local government, state institutions
- 124 representatives of commercial sectors, utilities, banks

of which 25 people accepted the invitation and attended the seminar. The experience acquired through the seminar complements the results of the on-line questionnaire.

During the preparatory phase, the organizers were in discussions with leading ICT experts, managers and directors from various types of sectors (datacenters, critical infrastructure, public

safety and security, banks) about the importance of secure delivery of sharp time and frequency to their infrastructures leading to the following conclusions:

- Most of the CEO, CFO and COO underestimate the risks and threats connected with the time synchronization from GNSS and other types of non-guaranteed services.
- ICT managers are facing a lot of other “hot themes” like General Data Protection Regulations and cybersecurity laws, which set aside TF related issues.
- Most of ICT technicians are persuaded that the theme of the time delivery has nothing to do with them, because "they have the own time source" (which in many cases is an NTP server synchronized just by GPS/GNSS).

During the seminar after presentations on fundamental concepts of time and frequency dissemination and optical fiber links, a paper version of the questionnaire was given to the attendees to fill out. The main results are:

- Respondents expressed the significant need to have reliable time in their network. The average mark of the importance of reliable time is 4.75, based on a scale from 1 to 5 where 1 is unimportant and 5 is very important.
- Respondents expressed the significant need to have stable time in their network. The average mark of the importance of stable time is 4.5 of all answers, based on a scale from 1 to 5 where 1 is unimportant and 5 is very important.
- 75% respondents answered, that their organization needs to have “Legal time” and that their organization requires time monitoring.

In general, this seminar shows that it is important to educate people on TF issues, as many might not be aware of the importance of TF references for various different applications.

6 CONCLUSIONS

This report presents the results of the questionnaire on the need for TF reference signals focusing on users outside the community of metrology and RIs. The survey was sent out to more than 260 organizations and this report compiled the answers of mainly 64 respondents, which corresponds to a response rate of about 25%. TF references are relevant for most of the respondents, and a wide range of different organizations are represented in the answers. Among the different types of organizations which answered, the category the most represented are SMEs (about 30%). Given the diversity of the respondents, it is not surprising that there is a high degree of variability in the replies. An example of this is the number of nodes maintained by a user and the distance between the nodes.

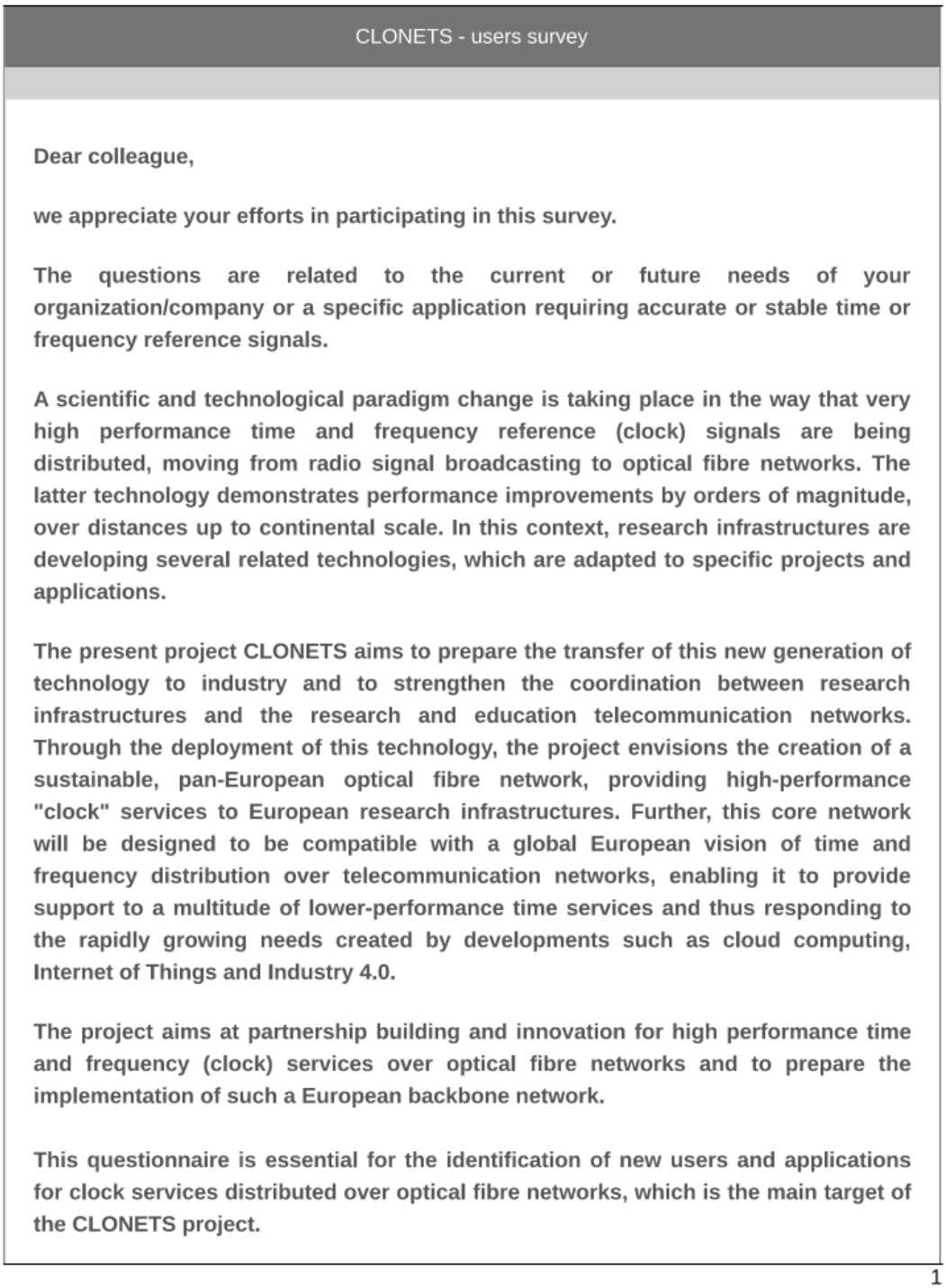
The relatively low number of answers means that it is not appropriate to carry out sophisticated analyses and draw detailed conclusions. Instead we have identified major trends in the responses. Overall, frequency reference signals are employed more frequently than time reference signals and thus are considered as slightly more relevant. The questionnaire indicates that TF reference signals are mainly considered to add value by improving the quality of the application in question. Generally necessary performance thresholds are given as:

- Better than 10^{-11} in relative frequency stability (both short-term and long-term);
- Better than 1 μs in terms of time jitter and timing accuracy.

Currently, frequency reference signals are mainly employed in the MHz range, with the optical domain primarily being of interest to the *Sensing & Instrumentation* sector. However, in the future, the optical domain is generally expected to play a more important role. While approximately half of the frequency reference signals are imported from external providers and half are produced internally, time reference signals are for the most part imported. Another general difference between frequency and time references is the need for traceability. Approximately two thirds of time reference signals require UTC traceability, while only approximately half of the frequency reference signals need to be certified.

The insights gained from this survey provide the CLONETS Consortium with an important starting point for more thoroughly understanding the TF needs of organizations and companies beyond RIs.

ANNEX 1. THE USER NEEDS SURVEY QUESTIONNAIRE



CLONETS - users survey

Dear colleague,

we appreciate your efforts in participating in this survey.

The questions are related to the current or future needs of your organization/company or a specific application requiring accurate or stable time or frequency reference signals.

A scientific and technological paradigm change is taking place in the way that very high performance time and frequency reference (clock) signals are being distributed, moving from radio signal broadcasting to optical fibre networks. The latter technology demonstrates performance improvements by orders of magnitude, over distances up to continental scale. In this context, research infrastructures are developing several related technologies, which are adapted to specific projects and applications.

The present project CLONETS aims to prepare the transfer of this new generation of technology to industry and to strengthen the coordination between research infrastructures and the research and education telecommunication networks. Through the deployment of this technology, the project envisions the creation of a sustainable, pan-European optical fibre network, providing high-performance "clock" services to European research infrastructures. Further, this core network will be designed to be compatible with a global European vision of time and frequency distribution over telecommunication networks, enabling it to provide support to a multitude of lower-performance time services and thus responding to the rapidly growing needs created by developments such as cloud computing, Internet of Things and Industry 4.0.

The project aims at partnership building and innovation for high performance time and frequency (clock) services over optical fibre networks and to prepare the implementation of such a European backbone network.

This questionnaire is essential for the identification of new users and applications for clock services distributed over optical fibre networks, which is the main target of the CLONETS project.

1

The questionnaire is split into several pages. Depending on your answers some of them might be automatically skipped. All questions are optional, except those necessary for the working of the questionnaire itself.

Personal data protection:

We do not require your identification or contact information to complete this questionnaire. However we would appreciate your providing it, if you would like to receive further information about the project. CLONETS processes personal data only for non-commercial purposes and in compliance with EU and national private data protection legislation. For full details see the CLONETS Personal Data Protection Informa<

Note:

The CLONETS project (CLOck NETwork Services: Strategy and innovation for clock services over optical-fibre networks) receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731107.

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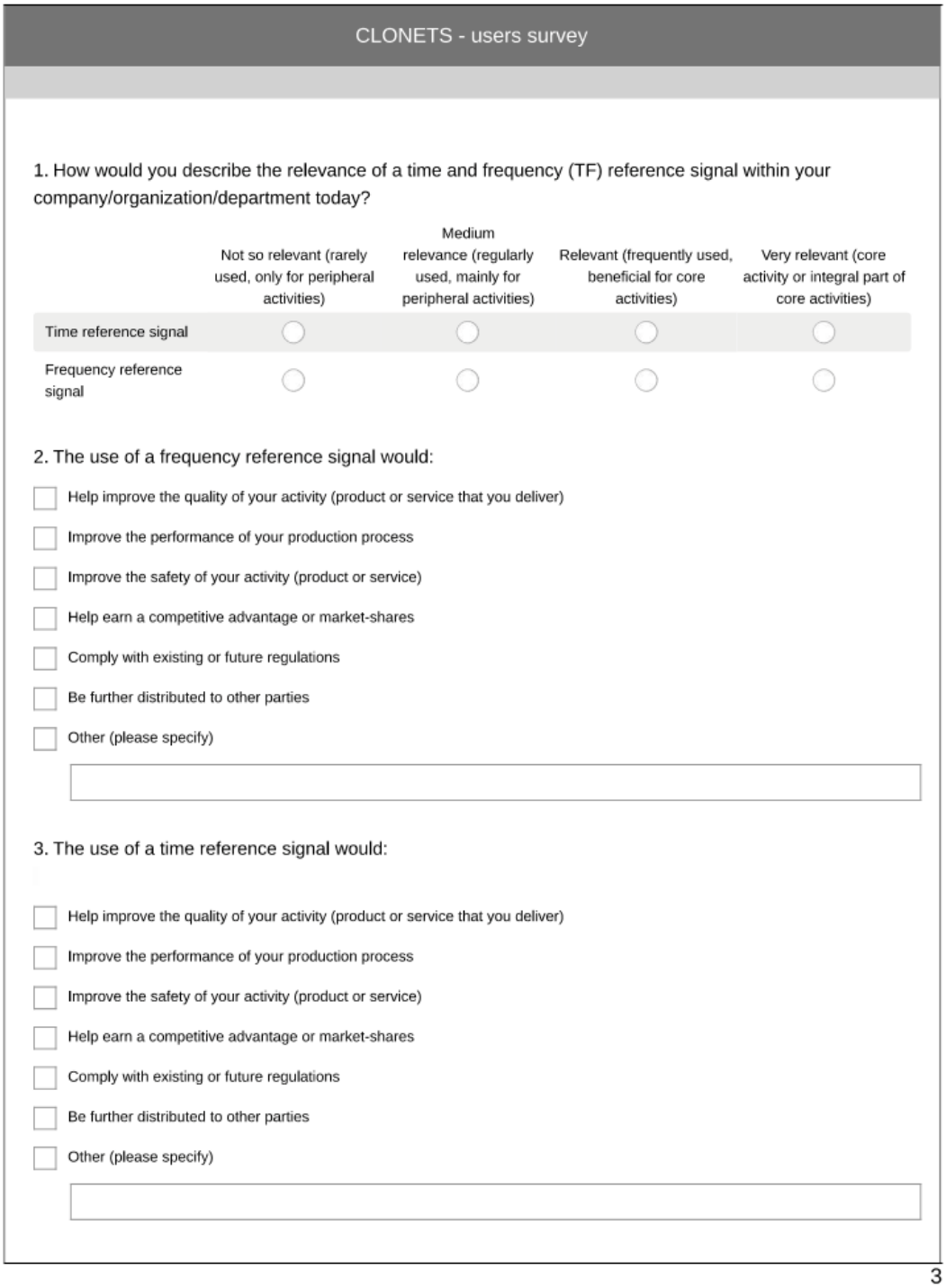

CLONETS - users survey

1. How would you describe the relevance of a time and frequency (TF) reference signal within your company/organization/department today?

	Not so relevant (rarely used, only for peripheral activities)	Medium relevance (regularly used, mainly for peripheral activities)	Relevant (frequently used, beneficial for core activities)	Very relevant (core activity or integral part of core activities)
Time reference signal	○	○	○	○
Frequency reference signal	○	○	○	○

2. The use of a frequency reference signal would:

- ☐ Help improve the quality of your activity (product or service that you deliver)
- ☐ Improve the performance of your production process
- ☐ Improve the safety of your activity (product or service)
- ☐ Help earn a competitive advantage or market-shares
- ☐ Comply with existing or future regulations
- ☐ Be further distributed to other parties
- ☐ Other (please specify)

3. The use of a time reference signal would:

- ☐ Help improve the quality of your activity (product or service that you deliver)
- ☐ Improve the performance of your production process
- ☐ Improve the safety of your activity (product or service)
- ☐ Help earn a competitive advantage or market-shares
- ☐ Comply with existing or future regulations
- ☐ Be further distributed to other parties
- ☐ Other (please specify)

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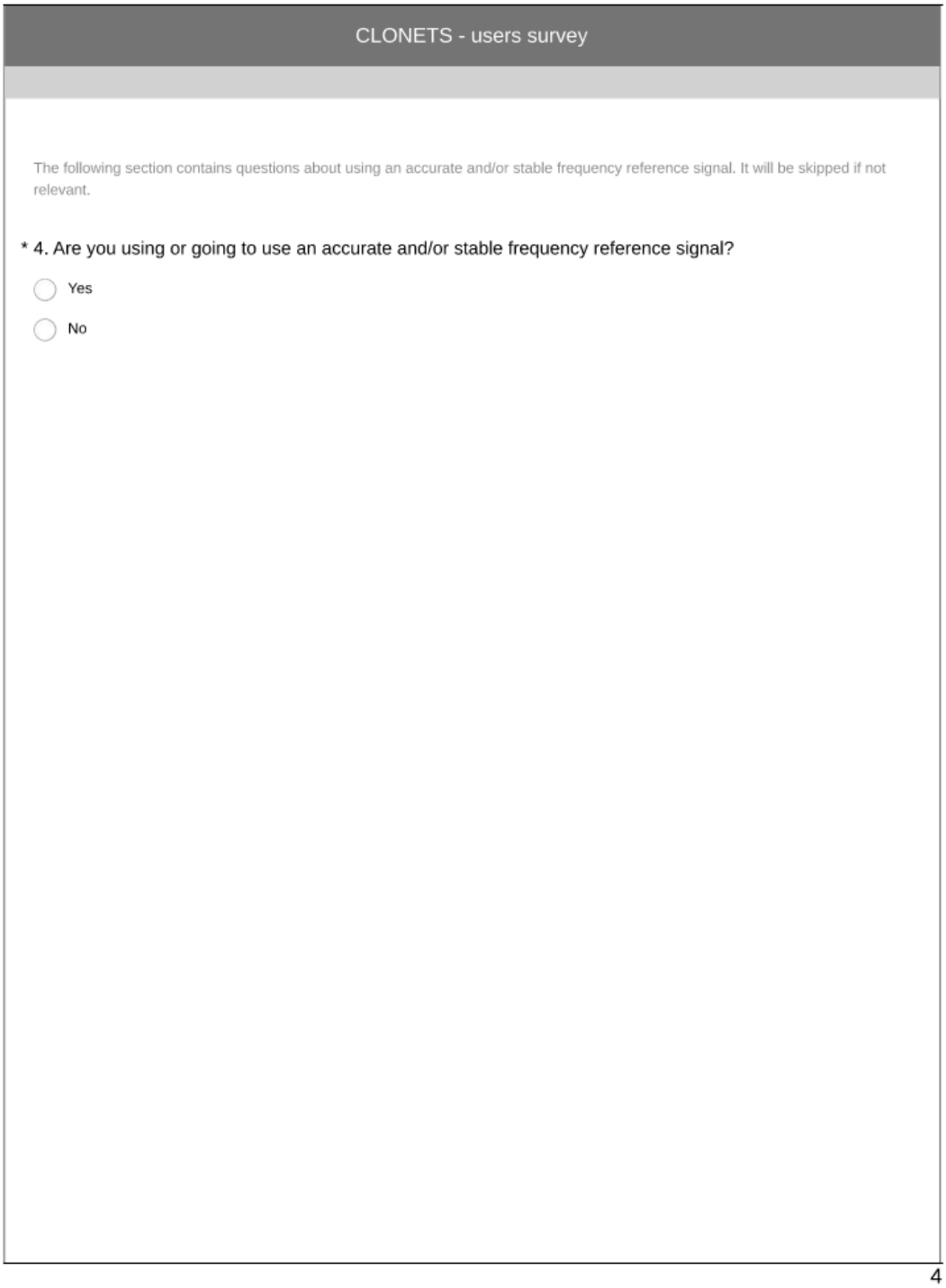


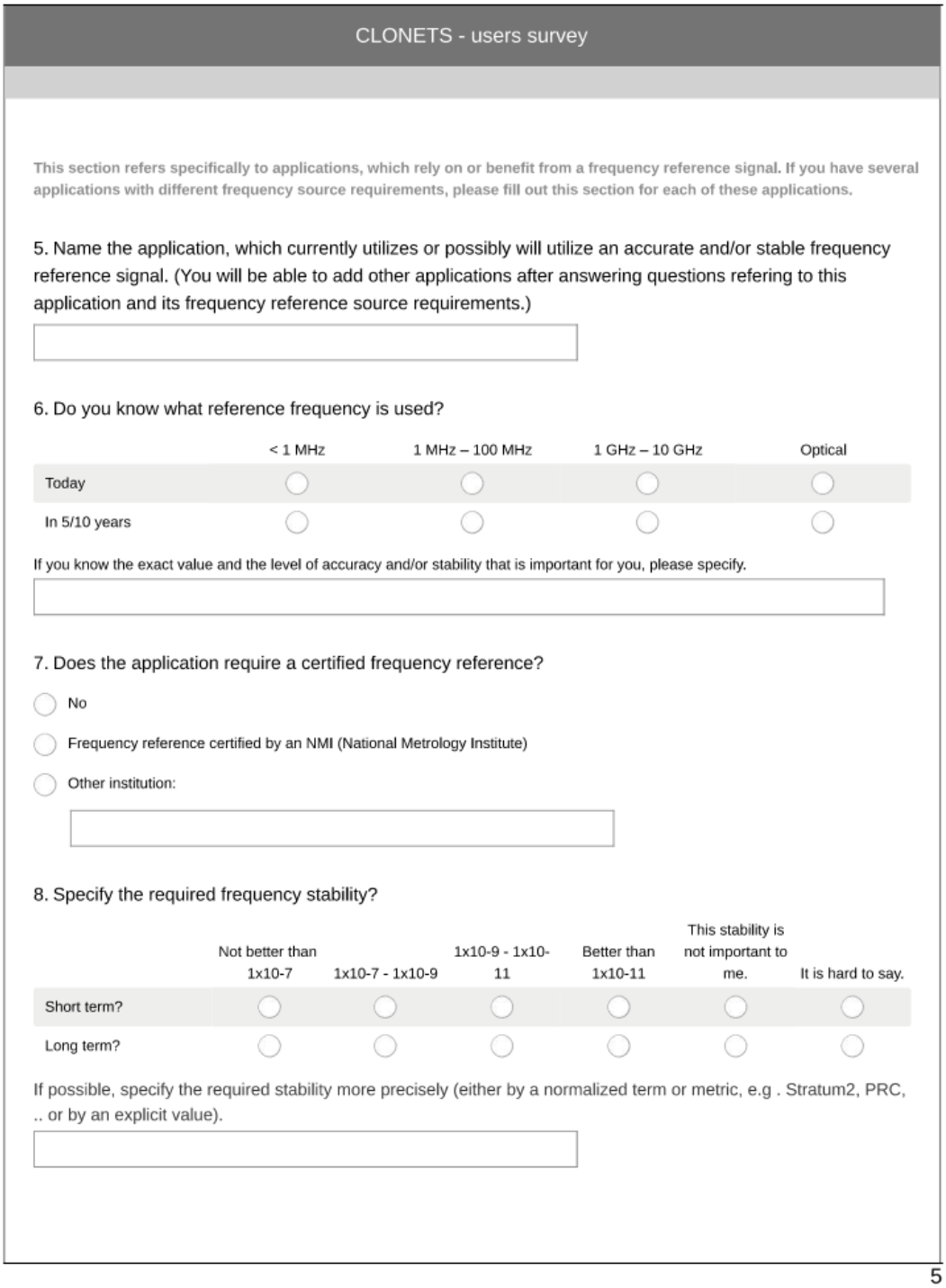
CLONETS - users survey

The following section contains questions about using an accurate and/or stable frequency reference signal. It will be skipped if not relevant.

* 4. Are you using or going to use an accurate and/or stable frequency reference signal?

- Yes
- No

4



CLONETS - users survey

This section refers specifically to applications, which rely on or benefit from a frequency reference signal. If you have several applications with different frequency source requirements, please fill out this section for each of these applications.

5. Name the application, which currently utilizes or possibly will utilize an accurate and/or stable frequency reference signal. (You will be able to add other applications after answering questions refering to this application and its frequency reference source requirements.)

6. Do you know what reference frequency is used?

	< 1 MHz	1 MHz – 100 MHz	1 GHz – 10 GHz	Optical
Today	◯	◯	◯	◯
In 5/10 years	◯	◯	◯	◯

If you know the exact value and the level of accuracy and/or stability that is important for you, please specify.

7. Does the application require a certified frequency reference?

- ◯ No
- ◯ Frequency reference certified by an NMI (National Metrology Institute)
- ◯ Other institution:

8. Specify the required frequency stability?

	Not better than 1x10-7	1x10-7 - 1x10-9	1x10-9 - 1x10-11	Better than 1x10-11	This stability is not important to me.	It is hard to say.
Short term?	◯	◯	◯	◯	◯	◯
Long term?	◯	◯	◯	◯	◯	◯

If possible, specify the required stability more precisely (either by a normalized term or metric, e.g . Stratum2, PRC, .. or by an explicit value).

5

9. Please rank the usefulness of the following frequency reference signal characteristics for your activity.

	Completely irrelevant	Low	Standard	High	Critical
Stability	○	○	○	○	○
Accuracy	○	○	○	○	○
Reliability/resilience	○	○	○	○	○
Traceability	○	○	○	○	○
Secondary source (e.g. backup, independent source)	○	○	○	○	○

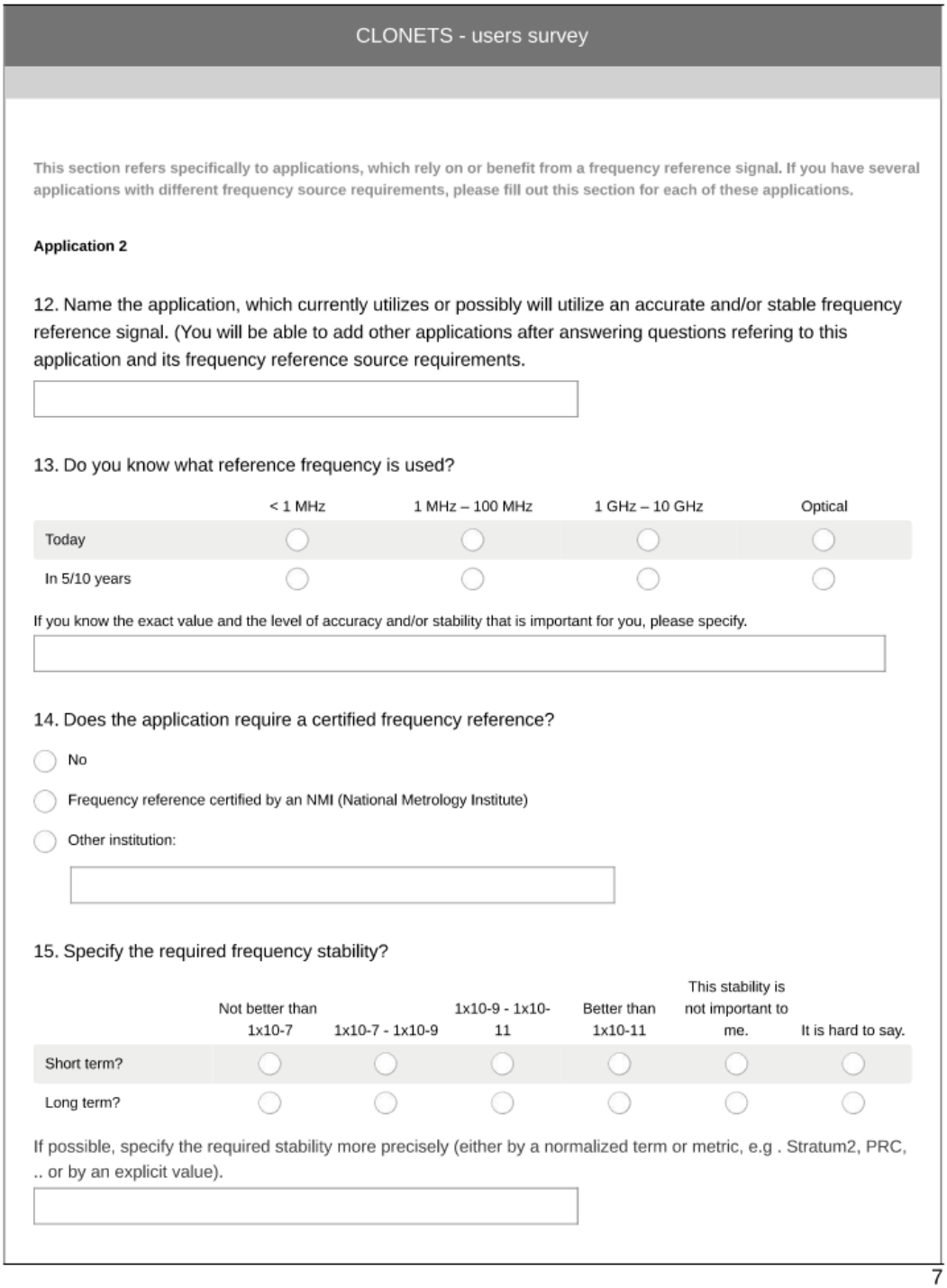
10. What is the origin of the frequency reference signal you use?

- ☐ Internal production (an oscillator owned and operated by your organization)
- ☐ Import (the external reference signal is delivered to you from someone else, e.g. by GPS transfer)
- ☐ Other:

* 11. Do you use other applications ?

- ○ Yes
- ○ No

6



CLONETS - users survey

This section refers specifically to applications, which rely on or benefit from a frequency reference signal. If you have several applications with different frequency source requirements, please fill out this section for each of these applications.

Application 2

12. Name the application, which currently utilizes or possibly will utilize an accurate and/or stable frequency reference signal. (You will be able to add other applications after answering questions refering to this application and its frequency reference source requirements.

13. Do you know what reference frequency is used?

	< 1 MHz	1 MHz – 100 MHz	1 GHz – 10 GHz	Optical
Today	○	○	○	○
In 5/10 years	○	○	○	○

If you know the exact value and the level of accuracy and/or stability that is important for you, please specify.

14. Does the application require a certified frequency reference?

- ○ No
- ○ Frequency reference certified by an NMI (National Metrology Institute)
- ○ Other institution:

15. Specify the required frequency stability?

	Not better than 1x10-7	1x10-7 - 1x10-9	1x10-9 - 1x10-11	Better than 1x10-11	This stability is not important to me.	It is hard to say.
Short term?	○	○	○	○	○	○
Long term?	○	○	○	○	○	○

If possible, specify the required stability more precisely (either by a normalized term or metric, e.g . Stratum2, PRC, .. or by an explicit value).

7

16. Please rank the following characteristics of a useful frequency reference signal for your activity.

	Completely irrelevant	Low	Standard	High	Critical
Stability	○	○	○	○	○
Accuracy	○	○	○	○	○
Reliability/resilience	○	○	○	○	○
Traceability	○	○	○	○	○
Secondary source (e.g. backup, independent source)	○	○	○	○	○

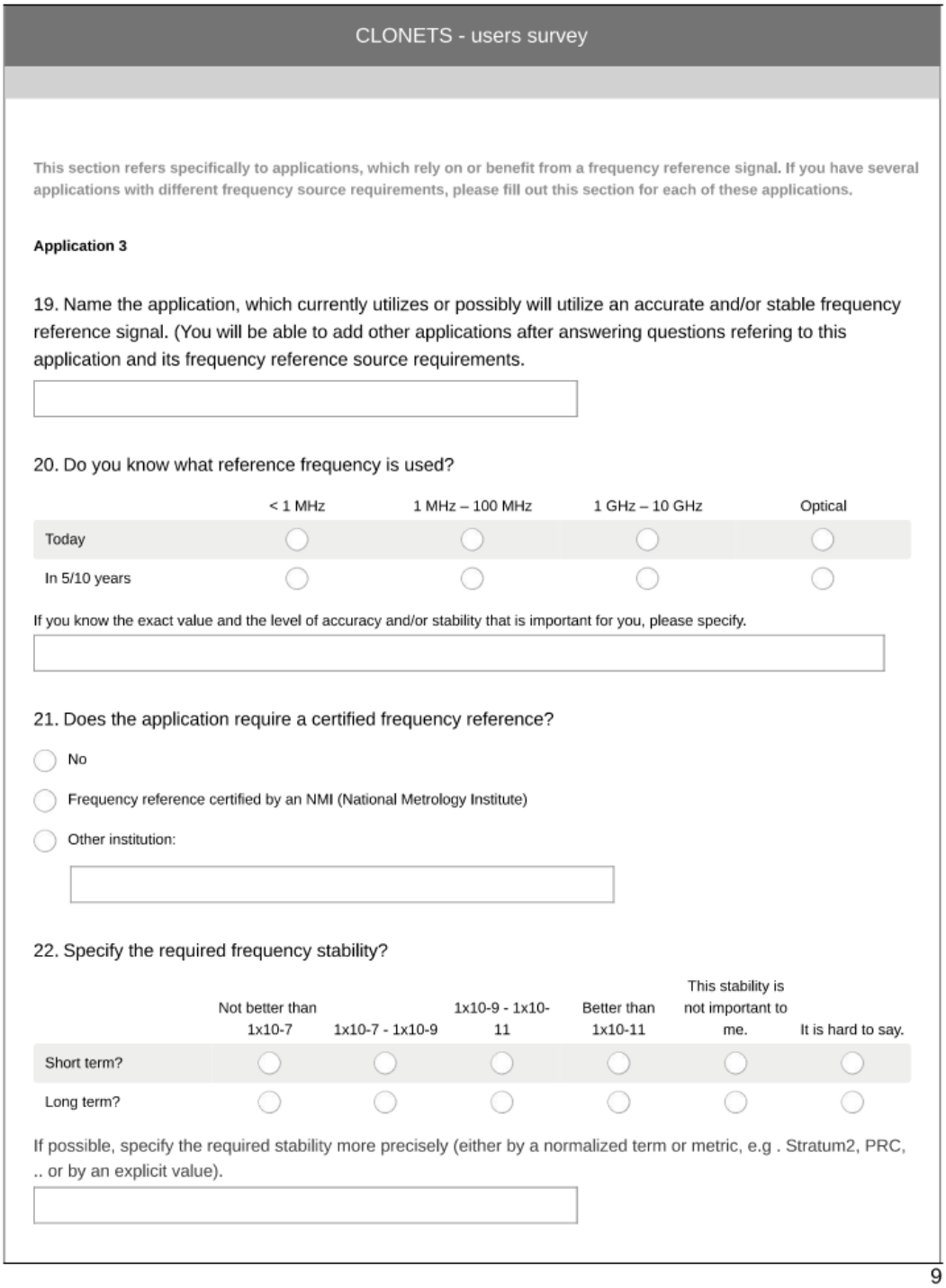
17. What is the origin of the frequency reference signal you use?

- ☐ Internal production (an oscillator owned and operated by your organization)
- ☐ Import (the external reference signal is delivered to you from someone else, e.g. by GPS transfer)
- ☐ Other:

* 18. Do you use other applications ?

- ○ Yes
- ○ No

8



CLONETS - users survey

This section refers specifically to applications, which rely on or benefit from a frequency reference signal. If you have several applications with different frequency source requirements, please fill out this section for each of these applications.

Application 3

19. Name the application, which currently utilizes or possibly will utilize an accurate and/or stable frequency reference signal. (You will be able to add other applications after answering questions refering to this application and its frequency reference source requirements.

20. Do you know what reference frequency is used?

	< 1 MHz	1 MHz – 100 MHz	1 GHz – 10 GHz	Optical
Today	○	○	○	○
In 5/10 years	○	○	○	○

If you know the exact value and the level of accuracy and/or stability that is important for you, please specify.

21. Does the application require a certified frequency reference?

- ○ No
- ○ Frequency reference certified by an NMI (National Metrology Institute)
- ○ Other institution:

22. Specify the required frequency stability?

	Not better than 1x10-7	1x10-7 - 1x10-9	1x10-9 - 1x10-11	Better than 1x10-11	This stability is not important to me.	It is hard to say.
Short term?	○	○	○	○	○	○
Long term?	○	○	○	○	○	○

If possible, specify the required stability more precisely (either by a normalized term or metric, e.g . Stratum2, PRC, .. or by an explicit value).

9

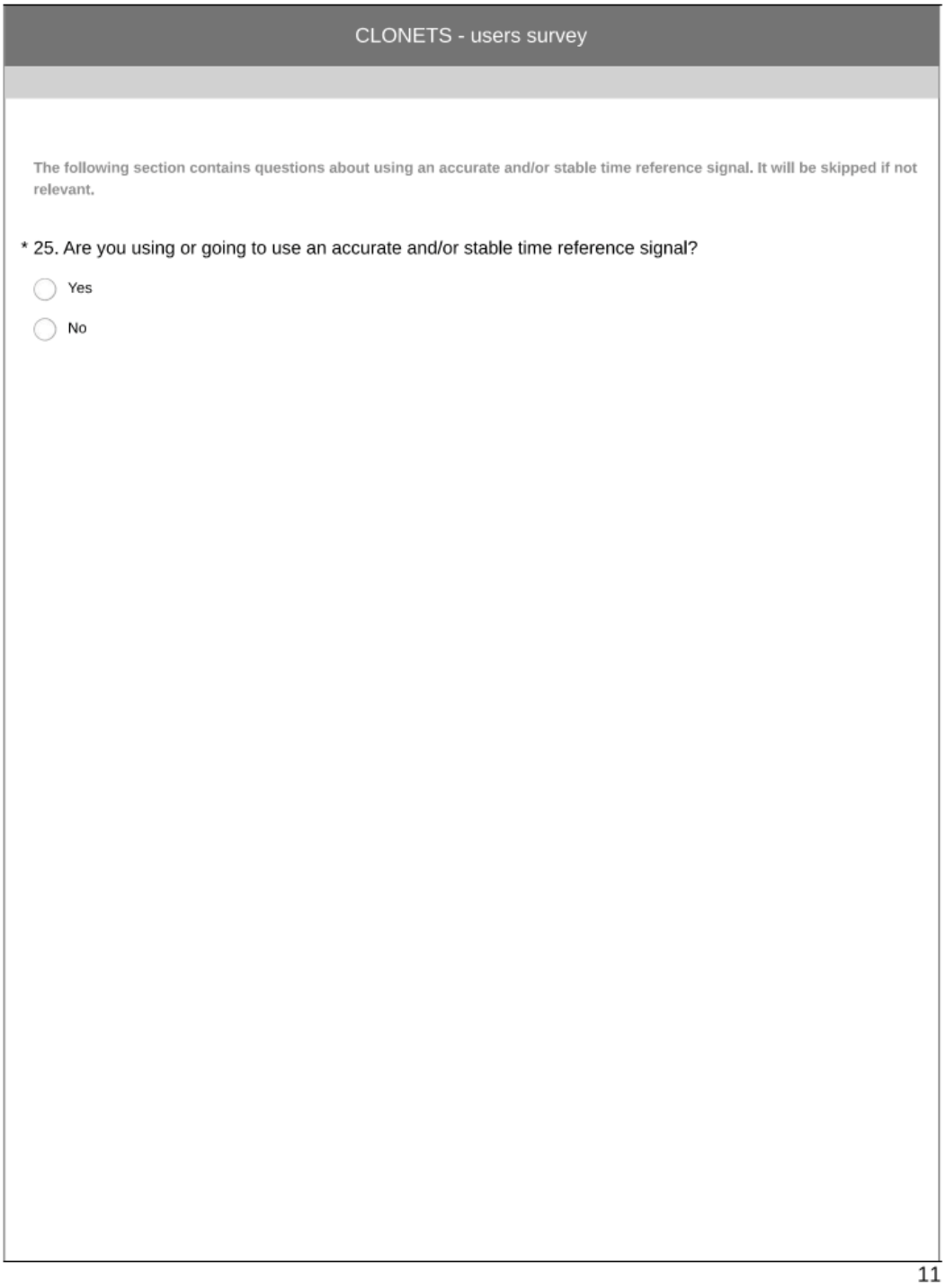
23. Please rank the following characteristics of a useful frequency reference signal for your activity.

	Completely irrelevant	Low	Standard	High	Critical
Stability	○	○	○	○	○
Accuracy	○	○	○	○	○
Reliability/resilience	○	○	○	○	○
Traceability	○	○	○	○	○
Secondary source (e.g. backup, independent source)	○	○	○	○	○

24. What is the origin of the frequency reference signal you use?

- ☐ Internal production (an oscillator owned and operated by your organization)
- ☐ Import (the external reference signal is delivered to you from someone else, e.g. by GPS transfer)
- ☐ Other:

10

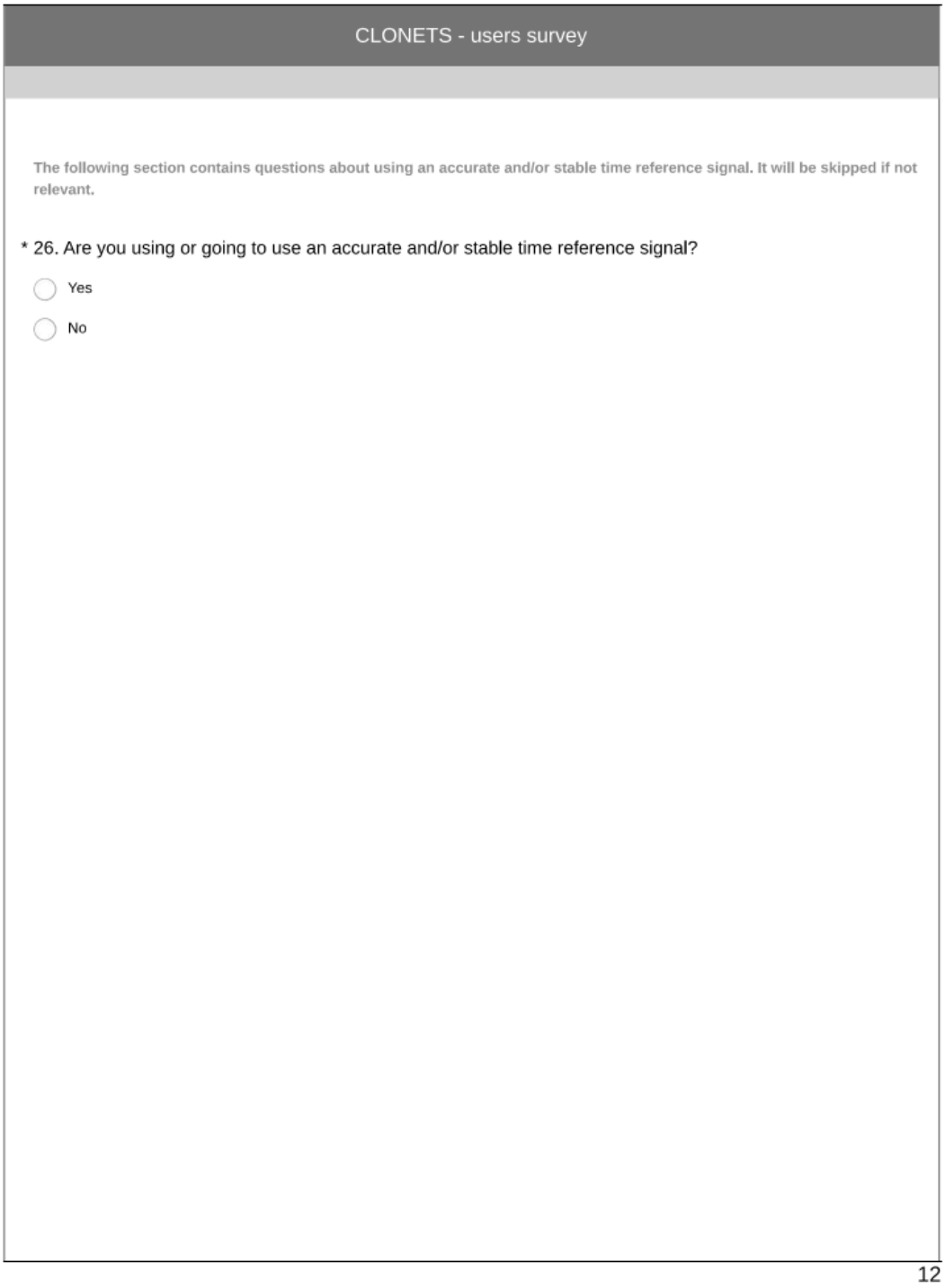

CLONETS - users survey

The following section contains questions about using an accurate and/or stable time reference signal. It will be skipped if not relevant.

* 25. Are you using or going to use an accurate and/or stable time reference signal?

- Yes
- No

11

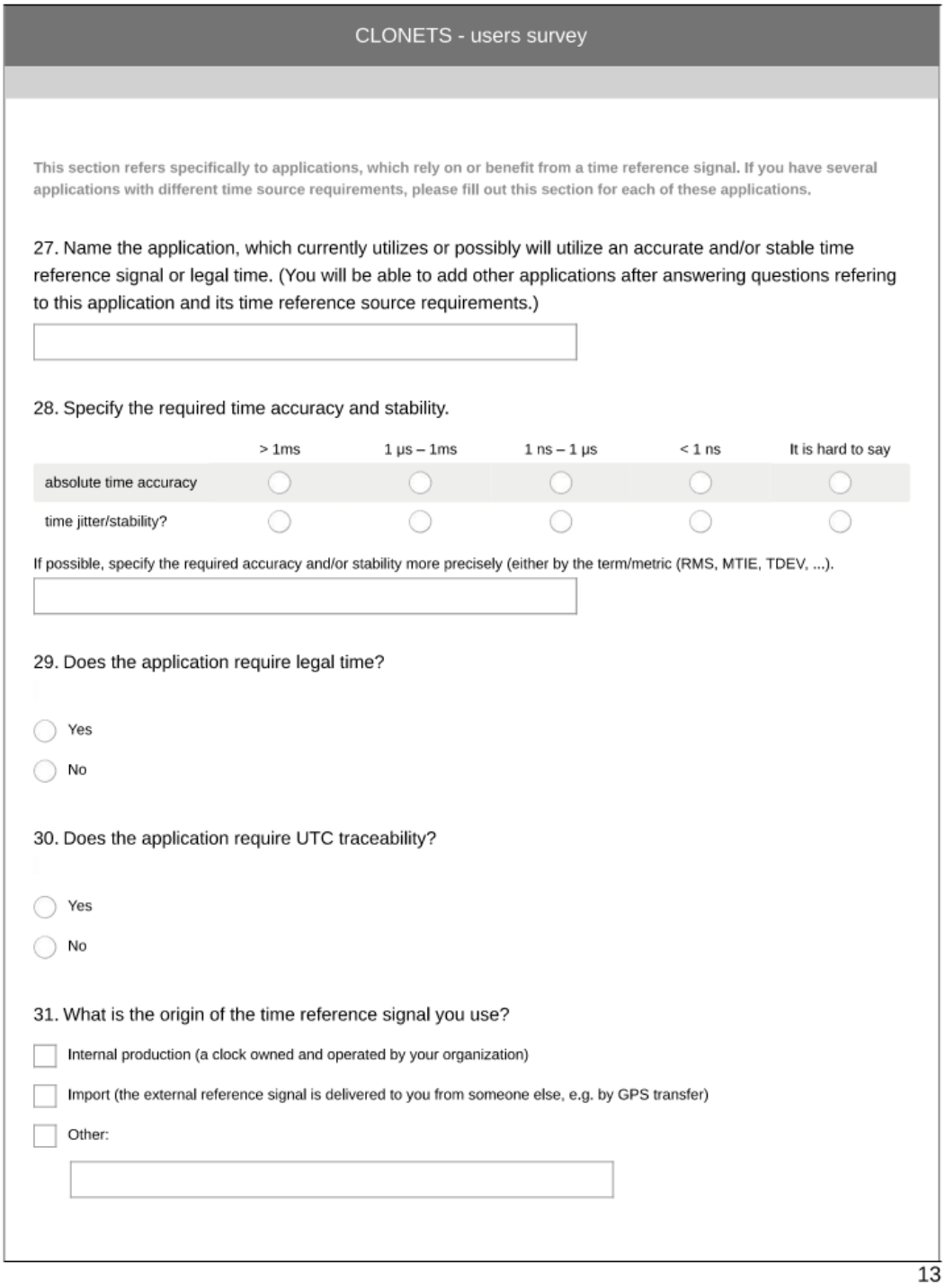

CLONETS - users survey

The following section contains questions about using an accurate and/or stable time reference signal. It will be skipped if not relevant.

* 26. Are you using or going to use an accurate and/or stable time reference signal?

- Yes
- No

12



CLONETS - users survey

This section refers specifically to applications, which rely on or benefit from a time reference signal. If you have several applications with different time source requirements, please fill out this section for each of these applications.

27. Name the application, which currently utilizes or possibly will utilize an accurate and/or stable time reference signal or legal time. (You will be able to add other applications after answering questions refering to this application and its time reference source requirements.)

28. Specify the required time accuracy and stability.

	> 1ms	1 µs – 1ms	1 ns – 1 µs	< 1 ns	It is hard to say
absolute time accuracy	○	○	○	○	○
time jitter/stability?	○	○	○	○	○

If possible, specify the required accuracy and/or stability more precisely (either by the term/metric (RMS, MTIE, TDEV, ...).

29. Does the application require legal time?

- ○ Yes
- ○ No

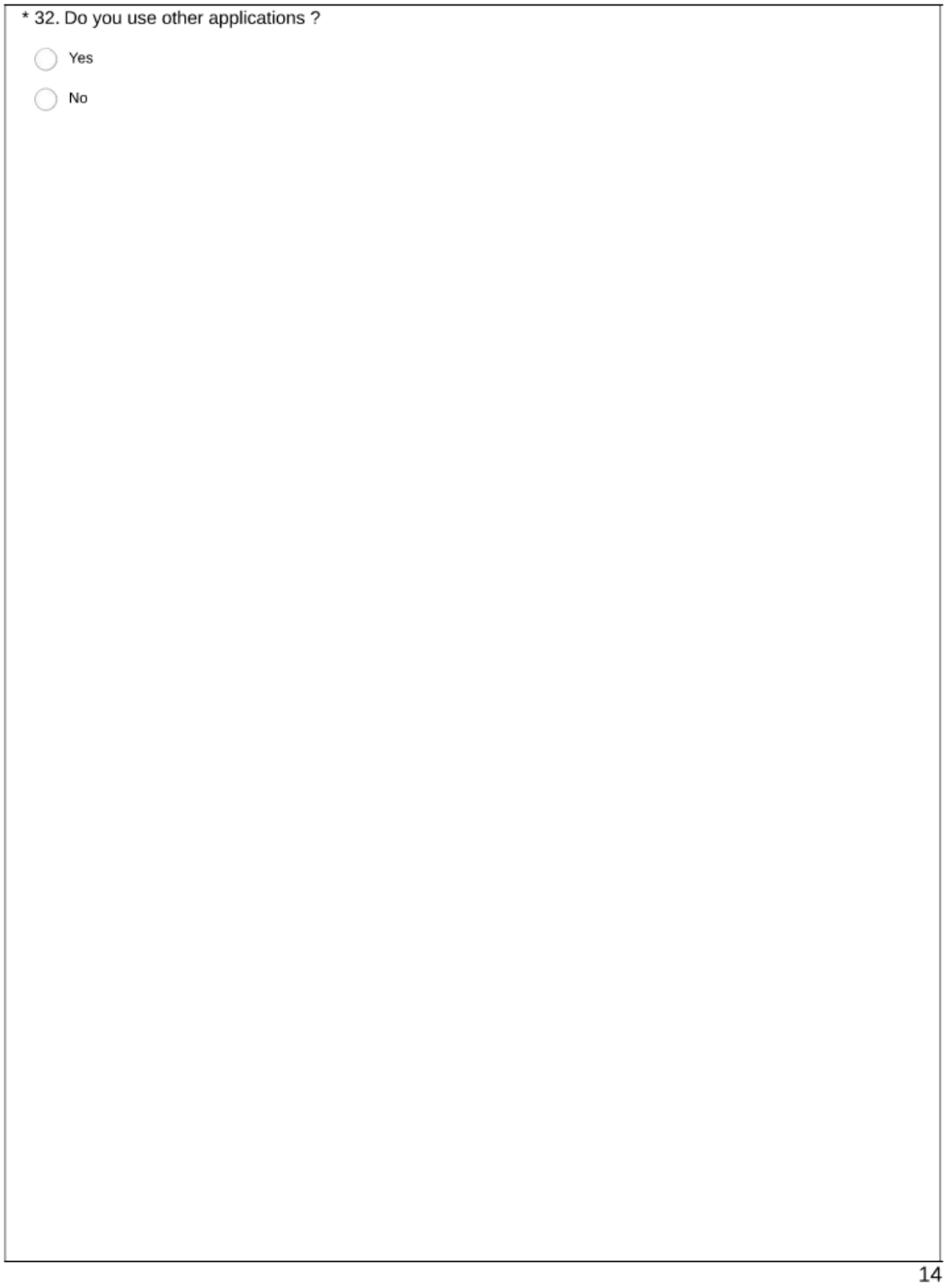
30. Does the application require UTC traceability?

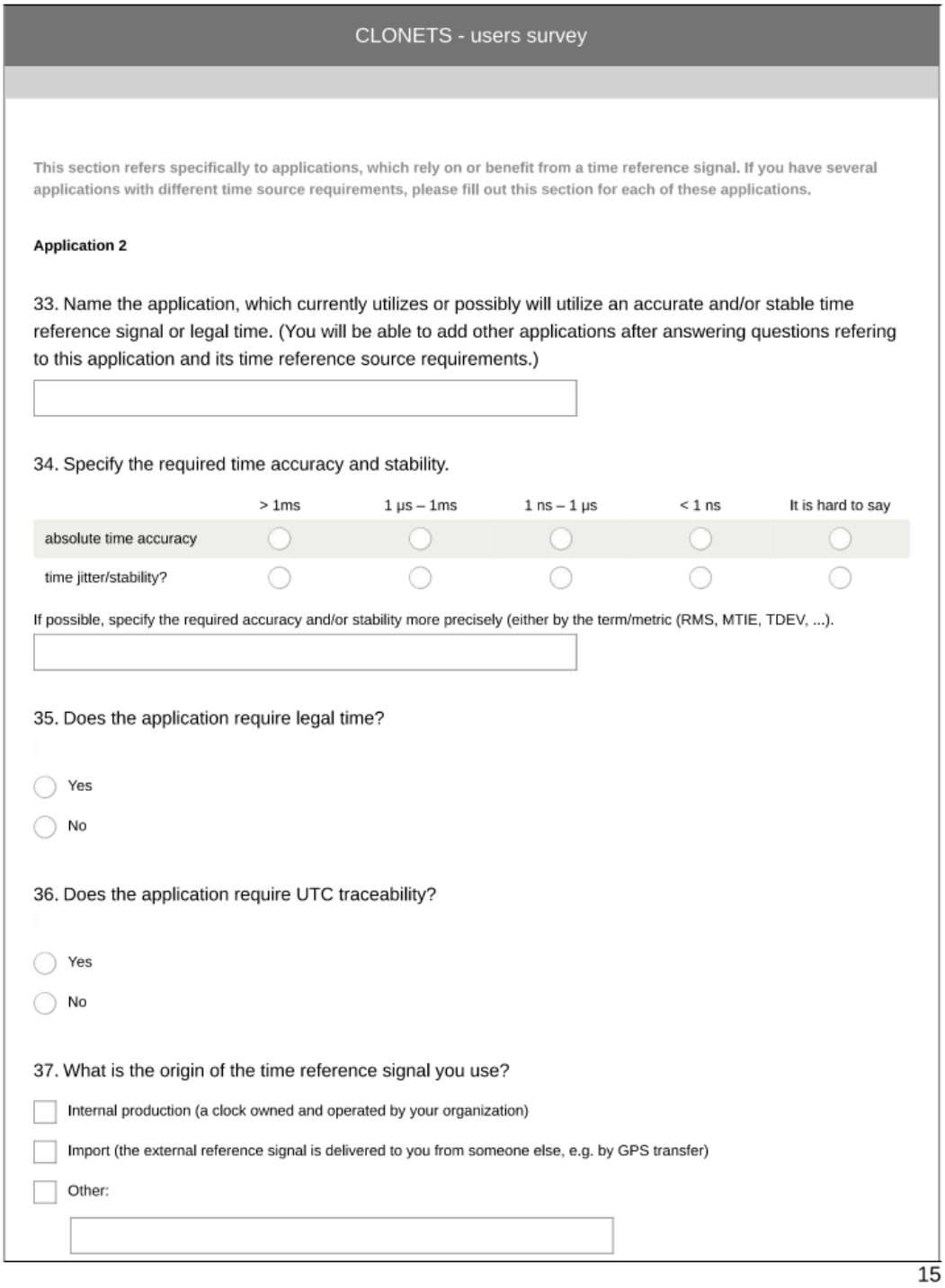
- ○ Yes
- ○ No

31. What is the origin of the time reference signal you use?

- ☐ Internal production (a clock owned and operated by your organization)
- ☐ Import (the external reference signal is delivered to you from someone else, e.g. by GPS transfer)
- ☐ Other:

13


* 32. Do you use other applications ?
Yes
No
14



CLONETS - users survey

This section refers specifically to applications, which rely on or benefit from a time reference signal. If you have several applications with different time source requirements, please fill out this section for each of these applications.

Application 2

33. Name the application, which currently utilizes or possibly will utilize an accurate and/or stable time reference signal or legal time. (You will be able to add other applications after answering questions refering to this application and its time reference source requirements.)

34. Specify the required time accuracy and stability.

	> 1ms	1 µs – 1ms	1 ns – 1 µs	< 1 ns	It is hard to say
absolute time accuracy	○	○	○	○	○
time jitter/stability?	○	○	○	○	○

If possible, specify the required accuracy and/or stability more precisely (either by the term/metric (RMS, MTIE, TDEV, ...).

35. Does the application require legal time?

- ○ Yes
- ○ No

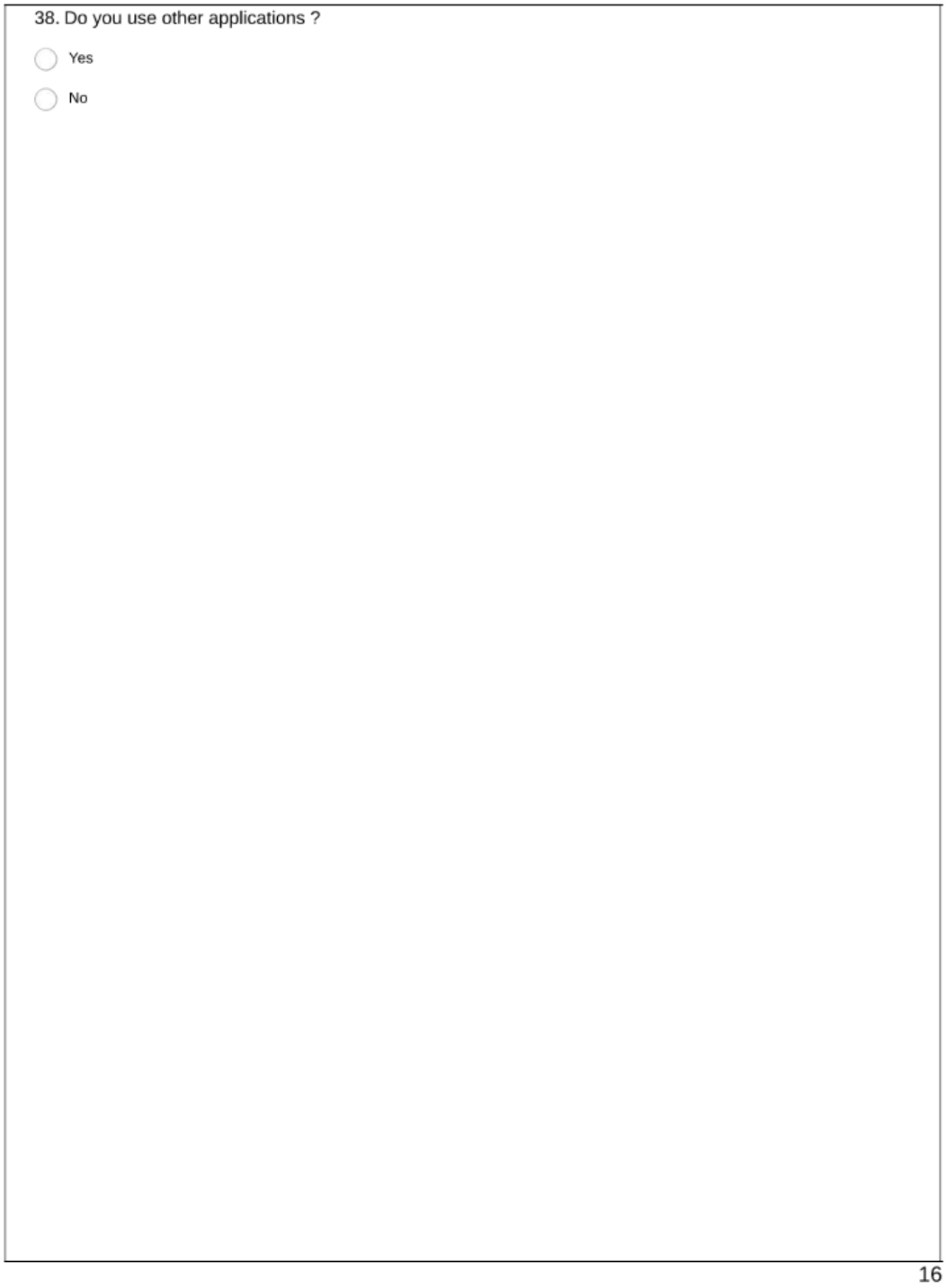
36. Does the application require UTC traceability?

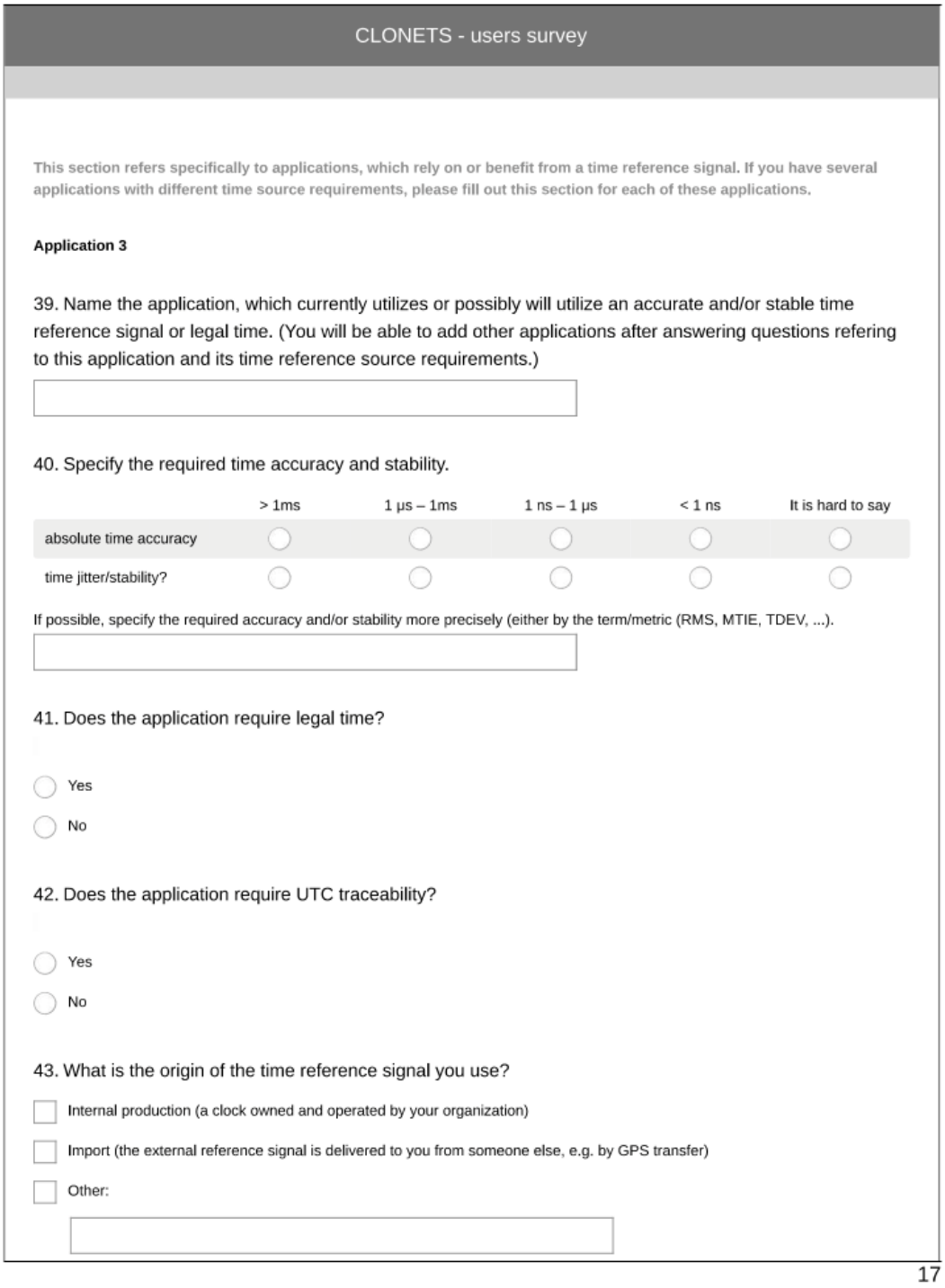
- ○ Yes
- ○ No

37. What is the origin of the time reference signal you use?

- ☐ Internal production (a clock owned and operated by your organization)
- ☐ Import (the external reference signal is delivered to you from someone else, e.g. by GPS transfer)
- ☐ Other:

15


38. Do you use other applications ?
Yes
No
16



CLONETS - users survey

This section refers specifically to applications, which rely on or benefit from a time reference signal. If you have several applications with different time source requirements, please fill out this section for each of these applications.

Application 3

39. Name the application, which currently utilizes or possibly will utilize an accurate and/or stable time reference signal or legal time. (You will be able to add other applications after answering questions refering to this application and its time reference source requirements.)

40. Specify the required time accuracy and stability.

	> 1ms	1 µs – 1ms	1 ns – 1 µs	< 1 ns	It is hard to say
absolute time accuracy	○	○	○	○	○
time jitter/stability?	○	○	○	○	○

If possible, specify the required accuracy and/or stability more precisely (either by the term/metric (RMS, MTIE, TDEV, ...).

41. Does the application require legal time?

- ○ Yes
- ○ No

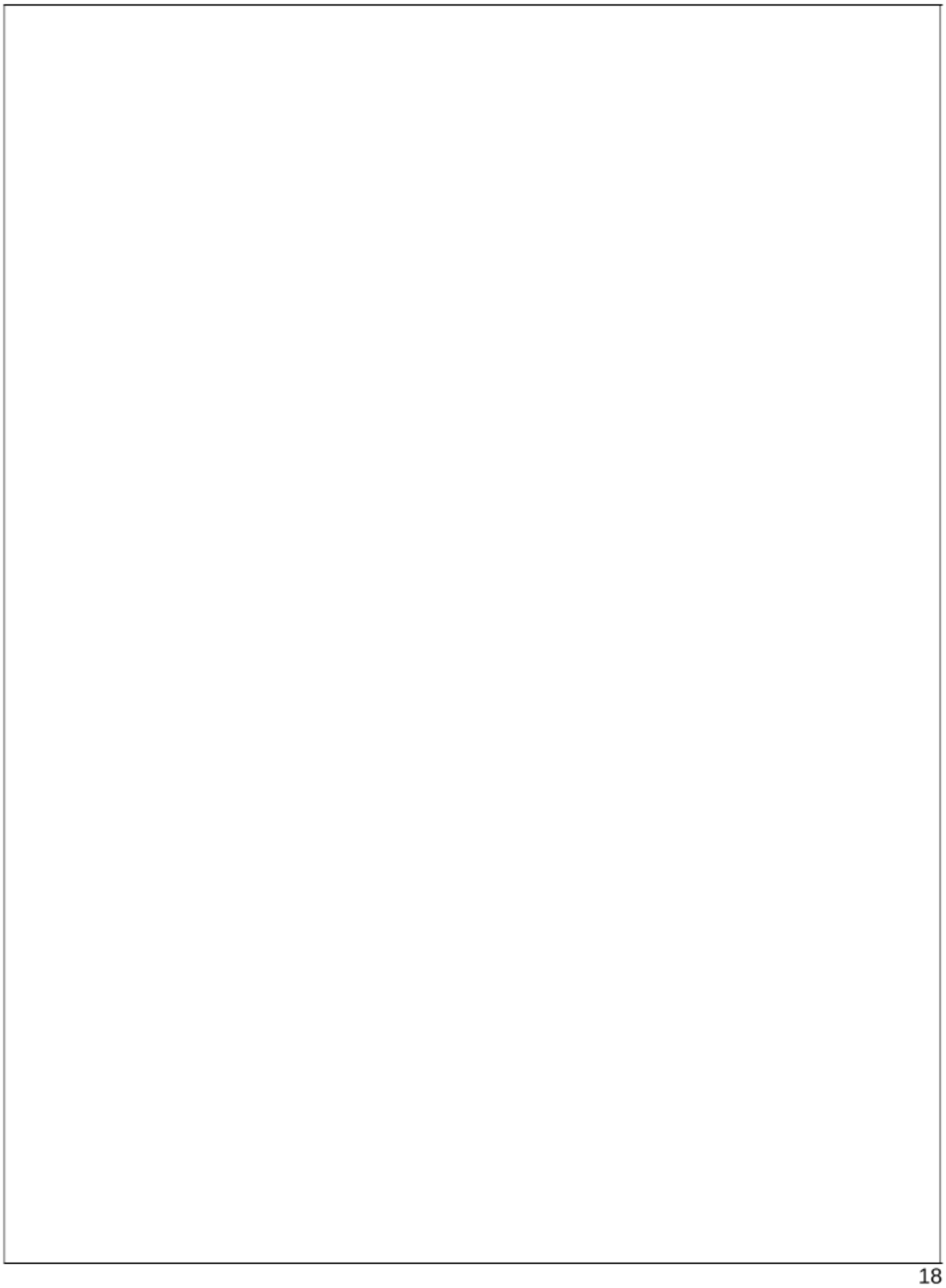
42. Does the application require UTC traceability?

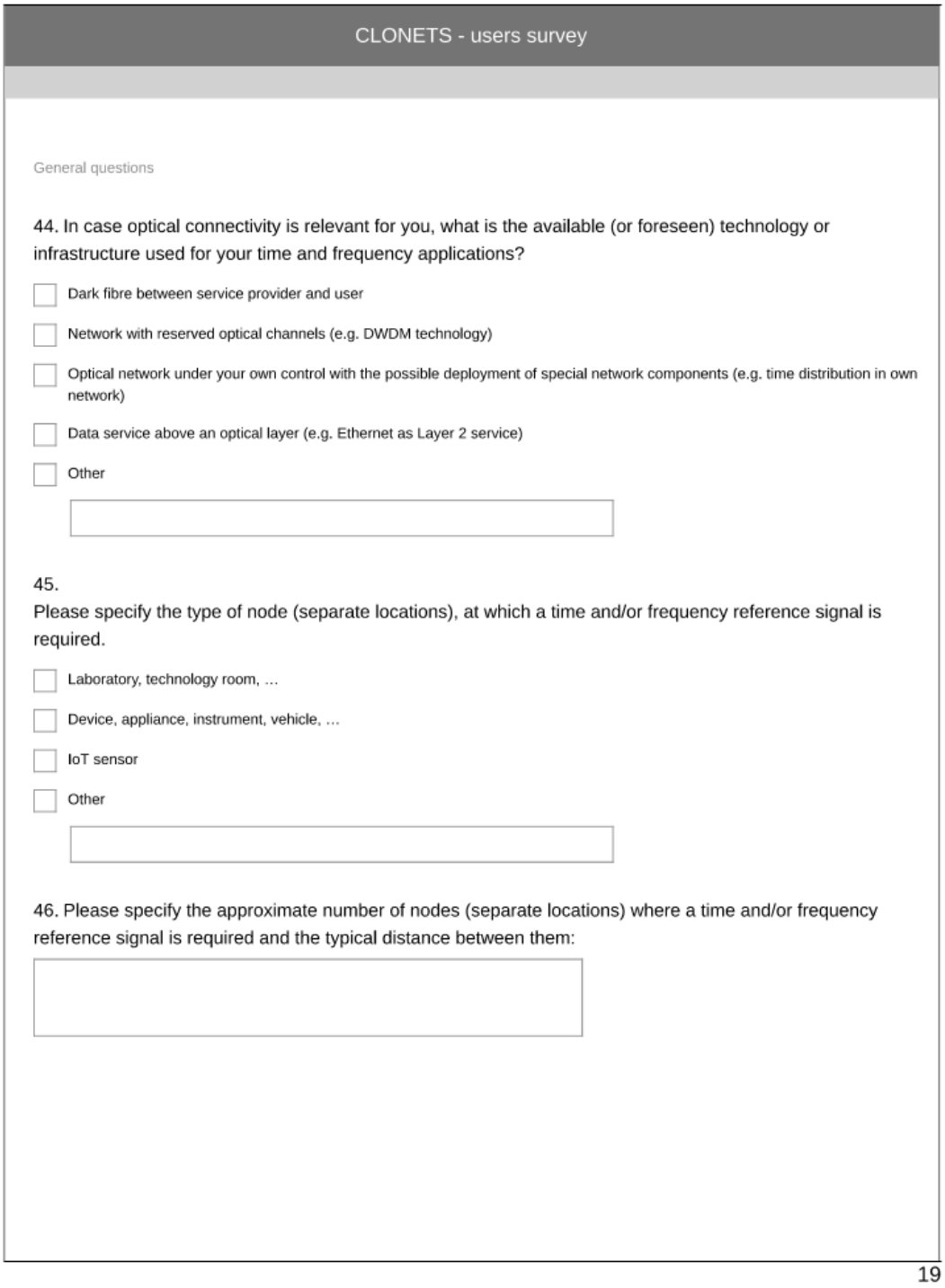
- ○ Yes
- ○ No

43. What is the origin of the time reference signal you use?

- ☐ Internal production (a clock owned and operated by your organization)
- ☐ Import (the external reference signal is delivered to you from someone else, e.g. by GPS transfer)
- ☐ Other:

17


18



CLONETS - users survey

General questions

44. In case optical connectivity is relevant for you, what is the available (or foreseen) technology or infrastructure used for your time and frequency applications?

- [ ] Dark fibre between service provider and user
- [ ] Network with reserved optical channels (e.g. DWDM technology)
- [ ] Optical network under your own control with the possible deployment of special network components (e.g. time distribution in own network)
- [ ] Data service above an optical layer (e.g. Ethernet as Layer 2 service)
- [ ] Other

45.
Please specify the type of node (separate locations), at which a time and/or frequency reference signal is required.

- [ ] Laboratory, technology room, …
- [ ] Device, appliance, instrument, vehicle, …
- [ ] IoT sensor
- [ ] Other

46. Please specify the approximate number of nodes (separate locations) where a time and/or frequency reference signal is required and the typical distance between them:

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47. If possible, specify the maximum distance between any two consecutive nodes.

- ◯ Below 1 km
- ◯ 1 km to 10 km
- ◯ 10 km to 100 km
- ◯ 100 km to 1000 km
- ◯ >1000 km

48. Have any failures related to the reception of the time and/or frequency signal occurred at your company/organization in the past?

- ◯ Yes
- ◯ No

If yes, how often has it occured?

49. What is an acceptable duration of interrupted access to the time and/or frequency reference signal at your company/organization?

50. Has your company/organization applied any redundancy procedures for failures related to the reception of a time and/or frequency reference signal?

- ◯ Yes
- ◯ No

51. Has your company/organization tested any redundancy procedures for failures related to the reception of a time and/or frequency reference signal?

- ◯ Yes
- ◯ No

52. Do you have any other comments regarding the use of accurate and/or stable time and/or frequency reference signals in your company/organization?

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CLONETS - users survey

53. What industry field does your company/organization operate in?

54. What is your country of operation?

Major country

Other country 1

Other country 2

Other country 3

55. Specify the approximate size of the company (number of employees):

- Up to 9 employees
- 10 to 49 employees
- 50 to 249 employees
- more than 250 employees
- I don´t know

56. What is the name of your company/organization?

57. What is your position held in the company/organization?

58. Could you provide your name, please?

Please tick also this box, if you authorise the CLONETS project participants to process your personal data as described in the Personal Data Protection Information Sheet, after the end of European Union Grant Agreement 731107.

My name is:

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59. If you would like to be informed about the progress of CLONETS, please provide your e-mail address.

60. Do you know about anyone else to send this questionnaire to? It would greatly help us.

61. Do you have any other comments or suggestions?

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