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Trustworthiness evaluation for autonomous networks including IMT-2020 and beyond

Technical Specification ITU FG-AN

Trustworthiness evaluation for autonomous networks including IMT-2020 and beyond

Summary

This is a deliverable of the ITU-T Focus Group on autonomous networks (FG-AN).

This Technical Specification analyses trustworthiness of autonomous networks. It provides the general process of trustworthiness evaluation, metrics and sub-metrics of trust and methods for evaluating trust in autonomous networks including IMT-2020 and beyond.

Keywords

Artificial intelligence, autonomous networks, basic principles, metrics requirements, trust, use cases.

Note

This is an informative ITU-T publication. Mandatory provisions such as those found in ITU-T Recommendations are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

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Trustworthiness evaluation for autonomous networks including IMT-2020 and beyond

1 Scope

This Technical Specification specifies trustworthiness evaluation for autonomous networks including IMT-2020 and beyond.

The scope of this Technical Specification includes:

- General process of trustworthiness evaluation for autonomous networks including IMT-2020 and beyond.
- Metrics and sub-metrics of trustworthiness evaluation for autonomous networks including IMT-2020 and beyond
- Methods of trustworthiness evaluation for autonomous networks including IMT-2020 and beyond.
- Quantitative ways of trustworthiness evaluation for autonomous networks including IMT-2020 and beyond.

2 References

[ITU-T Y.3051] Recommendation ITU-T Y.3051 (2017), *Basic principles of trusted environment in information and communication technology infrastructure.*

[ITU-T Y.3052] Recommendation ITU-T Y.3052 (2017), *Overview of trust provisioning in information and communication technology infrastructures and services.*

[ITU-T Y.3053] Recommendation ITU-T Y.3053 Amd.1 (2018), *Framework of trustworthy networking with trust-centric network domains.*

[ITU-T Y.3101] Recommendation ITU-T Y.3101 (2018), *Requirements of the IMT-2020 network.*

[ITU-T Y.3172] Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020.*

3 Definitions

3.1 Terms defined elsewhere

This Technical Specification uses the following terms defined elsewhere:

3.1.1 trust [ITU-T Y.3052]: Trust is the measurable belief and/or confidence which represents accumulated value from history and the expecting value for future.

3.1.2 IMT-2020 [ITU-T Y.3101]: Systems, system components, and related aspects that provide far more enhanced capabilities than those described in [b-ITU-R M.1645].

3.1.3 trusted AN [b-ITU-T TR-trust-an-cpr]: The autonomous network which is trustworthy enough (i.e. be able to work correctly as intended), so that the network can be authorized to partly or completely autonomously work.

3.1.4 trust in AN (TiAN) [b-ITU-T TR-trust-an-cpr]: A measurable and quantifiable degree of trustor's confidence to some AN to let it be governed by itself with minimal to no human intervention.

3.1.5 trustor in AN [b-ITU-T TR-trust-an-cpr]: The one who/which has the authority to authorize a network and/or the relevant entity be governed by itself with minimal to no human intervention.

3.1.6 trustee in AN [b-ITU-T TR-trust-an-cpr]: A network or a network relevant entity with autonomy capabilities which can be authorized to govern itself with minimal to no human intervention.

3.2 Terms defined in this Technical Specification

This Technical Specification defines the following terms:

None.

4 Abbreviations and acronyms

This Technical Specification uses the following abbreviations and acronyms:

AI Artificial intelligence

AN Autonomous network

CSP Communication service provider

ICT Information and communication technologies

ML Machine Learning

OAM Operation administration and maintenance

SDO Standard developing organization

TiAN Trust in autonomous network

5 Conventions

In this Technical Specification:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Technical Specification is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement needs not be present to claim conformance.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the trustee's implementation must provide the option, and the feature can be optionally enabled by trustor. Rather, it means the trustee may optionally provide the feature and still claim conformance with this Technical Specification.

6 Introduction

Artificial intelligence (AI), machine learning (ML) and relevant technologies are now being studied and gradually widely used in communication networks including IMT-2020 and beyond, and these technologies including AI are now being expected to enable network autonomy. For IMT-2020 and beyond, with the development of network systems and evolution of AI technology applications, operators are supposed to gradually handover their work and duties to network systems themselves which have self-X properties, i.e. the abilities to monitor, operate, recover, heal, protect, optimize, and reconfigure themselves, and these network systems with self-X properties are also known as autonomous networks (ANs) which means telecommunication system (including management system and network) with autonomy capabilities which is able to be governed by itself with minimal to no human intervention.

AN is enabled by AI and relevant intelligent technologies, when the network partly or totally govern by itself, the authorization of network governing will become an issue due to trust concerns. As decision-making behavior, trust is affected by past experience and associated predictions for the future. The study of trust in automated systems has been a topic of psychological study previously. However, AI poses unique challenges for user trust, the AI user has to trust the AI, changing the interaction between a user and a system into a relationship. Trust is a complexity-reduction mechanism, whose importance increases the less we know about the technology. In information and communication technologies (ICT). In ITU-T, trust is defined in [ITU-T Y.3052] as the measurable belief and/or confidence which represents accumulated value from history and the expecting value for the future, and trust can be one of the critical words to identify feature of "Future IS (Information Society) and their infrastructure".

In order to make trust for AN including IMT-2020 and beyond measurable and quantifiable, this Technical Specification specifies metrics and relevant methods for trustworthiness evaluation for AN including IMT-2020 and beyond. In this Technical Specification, the general process of trustworthiness evaluation has been illustrated, in the meantime, metrics and sub-metrics for trustworthiness evaluation have been specified with the quantitative ways of trustworthiness evaluation for AN including IMT-2020 and beyond.

7 General process of trustworthiness evaluation

7.1 TiAN evaluation process

In [b-ITU-T TR-trust-an-cpr], "trust in AN (TiAN)", as trustworthiness of AN, is defined as a measurable and quantifiable degree of trustor's confidence to some AN to let it be governed by itself with minimal to no human intervention; "trustor in AN" is defined as the one who/which has the authority to authorize a network and/or the relevant entity be governed by itself with minimal to no human intervention; "trustee in AN" is defined as a network or a network relevant entity with autonomy capabilities which can be authorized to govern itself with minimal to no human intervention.

TiAN has come up as trustworthiness of AN. In the meantime, it is evaluated as the objective part of trust for AN. During the TiAN evaluation, firstly, TiAN evaluation should be triggered, and then sub-metric(s) assessment before the metric(s) calculating, the TiAN will then calculate out from metric(s) as Figure 1 shows. Trustor in AN will make the consideration of following authorization(s), judgement(s), decision(s), etc. In Figure 1, the general process of TiAN evaluation is illustrated.

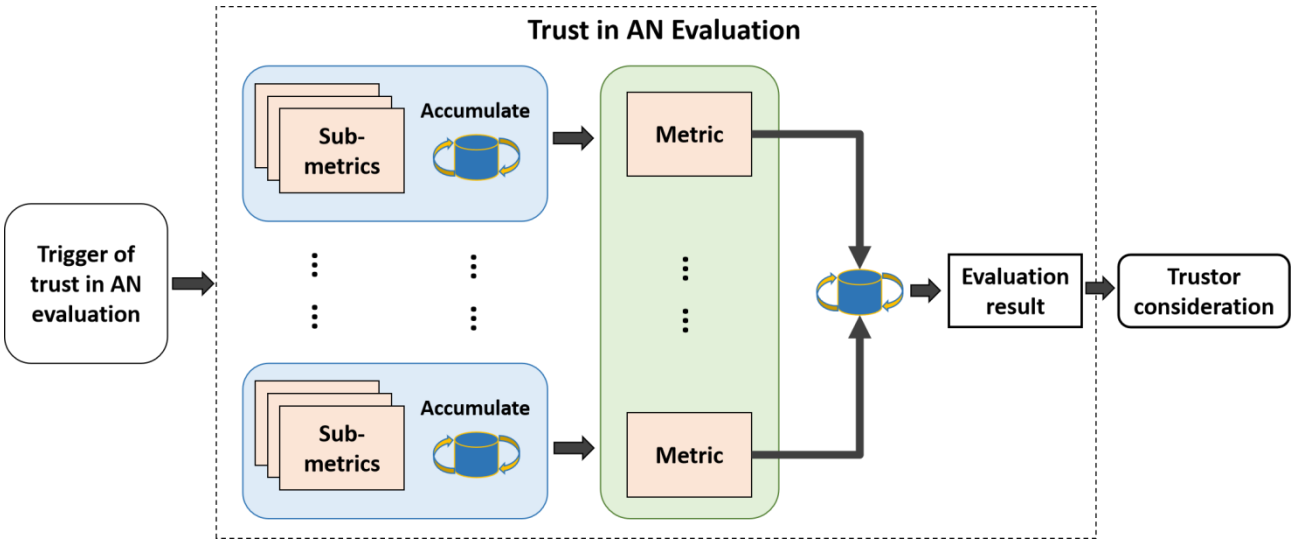

Figure 1 − General process of TiAN evaluation

- Evaluation environment: TiAN evaluation can take place in commercial networks, meanwhile, it also can take place in some test environment or simulation environment which is recommended to be mirrored from commercial networks, e.g. the digital twin network.
- Trigger: TiAN evaluation can be triggered by trustor in AN or trustee in AN itself, in following clause 7.2 it has listed the possible triggers of TiAN evaluation.
- Metric: metrics are those parameters or indicators which are set to make trust measurable and quantifiable, TiAN evaluation metrics have been illustrated in following clause 8.1, and the metric(s) will be calculated out from relevant sub-metric(s) which are assessed out manually or automatically with algorithm. Metric(s) in same TiAN evaluation should be unified with the same unit with relevant sub-metric(s).
- Sub-metric: each metric will set a series of sub-metrics, the assessment/evaluation results of sub-metrics should perform as the inputs for related metric in TiAN evaluation. Sub-metric(s) in a same TiAN evaluation are suggested to be unified in the same unit with the same unified way.
- Evaluation result(s): TiAN evaluation result(s) should be handed over to trustor in AN to take consideration(s), make decision(s) or judgement(s) of following authorization and progress. For TiAN evaluation result, it can be in in binary, coarse-grained, fine-grained, semantic-level, or other reasonable ways, depending on the practical need(s) and requirement(s) of trustor in AN.

7.2 Triggers of TiAN evaluation

TiAN evaluation can be triggered by trustor(s) of AN, and in order to self-trustworthy-prove, it also can be triggered by trustee in AN itself, in the meantime, the continuous TiAN evaluation can be triggered if necessary including periodically and aperiodically.

- Triggered by trustor(s) in AN: before authorization(s) to AN, trustor(s) in AN can trigger TiAN evaluation to achieve some objective and detailed trust value, i.e. TiAN, so that trustor in AN can make decision(s) of following authorization or authorization refusing.
- Triggered by trustee in AN itself: besides triggered by trustor in AN, TiAN evaluation can also be triggered by trustee in AN itself in order to self-trustworthy-prove, by some algorithm(s) or procedure(s) designing.
- Triggers of continuous TiAN evaluation: in order to maintain AN working continuously and autonomously, there should be some algorithm(s) or designed procedure(s) to continuously and periodically/aperiodically trigger TiAN evaluation.

8 Metrics of TiAN evaluation

8.1 Factors of basic principles to metrics

8.1.1 Trusted AN basic principles to TiAN evaluation metrics

Trusted AN basic principles, i.e. accountability, equitability, explainability, robustness, and safety, which comprise the fundamental properties of trusted AN, and they have been described in detail in [ITU-T TR-trust-an-cpr]. All of these basic principles cover and include fields of communications, computer science, ethics, psychology and game theory. AN can be trusted only when all of these basic principles being achieved, meanwhile, all basic principles are totally described in words abstractly, it is necessary to achieve some objective and quantitative parameters or indicators for TiAN evaluation, so metrics for TiAN evaluation have been refined and specified to make TiAN measurable and quantifiable. The generic relationship between basic principles of trusted AN and metrics for TiAN evaluation has been illustrate in following Figure 2.

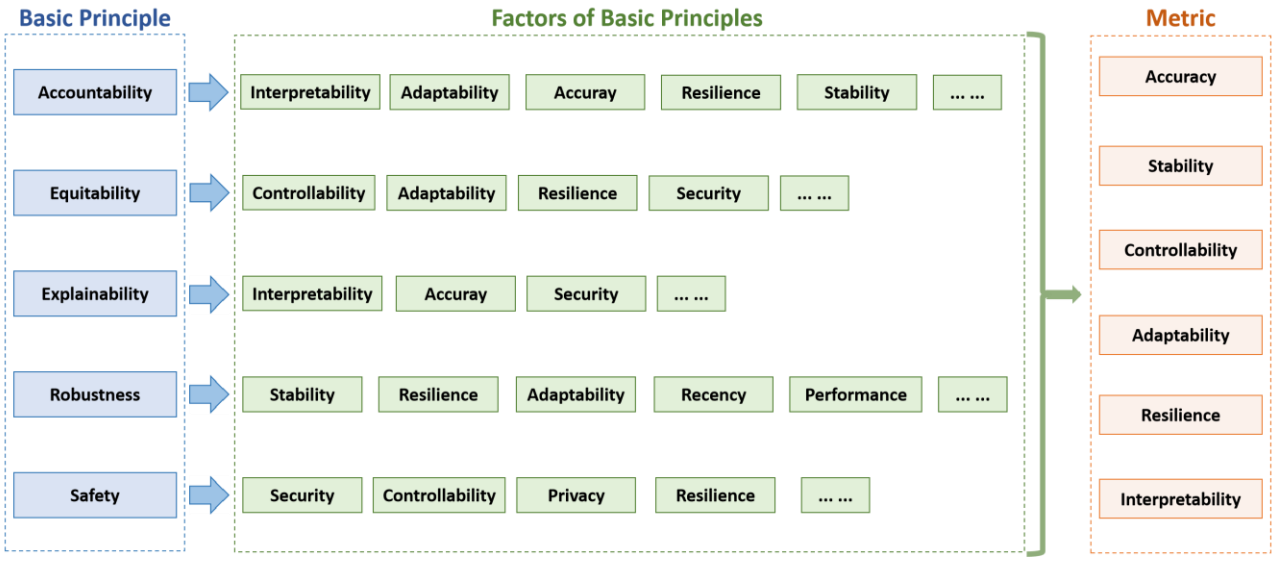

Figure 2 − Relationship between basic principles of trusted AN and metrics for TiAN evaluation

8.1.2 Factors of accountability

- **Interpretability**: as a factor of accountability, trustee in AN should do the self-interpreting to explain what has happened and processed, so that, it can be accurate and clear during tracing and auditing of responsibilities. The degree of interpretability will be part of the quantitative performance of accountability.
- **Adaptability**: as a factor of accountability, trustee in AN should be able to adapt to the corresponding environment(s) and the division of responsibilities needs adapt to the corresponding environment(s), parameter(s) and requirement(s) of trustor in AN. The degree of adaptability will be part of the quantitative performance of accountability.
- **Accuracy**: as a factor of accountability, the executive result(s) of trustee in AN is/are supposed to be accurate enough to be trusted, in the meantime, the division of duties is also supposed to be accurate and clear. The degree of accuracy will be part of the quantitative performance of accountability.
- **Resilience**: as a factor of accountability, trustee in AN should be flexible and resilient, when fallback happens it is necessary to return to the previous responsible entity. The degree of resilience will be part of the quantitative performance of accountability.

- **Stability**: as a factor of accountability, trustee in AN should be stable enough and mature enough, so that the responsibilities can be clearly and accurately divided. The degree of stability will be part of the quantitative performance of accountability.

8.1.3 Factors of equitability

- **Controllability**: as a factor of equitability, trustee in AN should be always under control of trustor in AN, relevant human staffs, or operation entities. It is necessary to avoid intended or unintended bias(es) or unfairness, i.e. treat all equally, and it should be taken over and under control if there is any bias or unfairness happening for trustee in AN. The degree of controllability will be part of the quantitative performance of equitability.
- **Adaptability**: as a factor of equitability, trustee in AN should adapt to the corresponding environment and related scenario, and it is necessary for trustee in AN to adjust itself to treat all without any bias(es) or unfairness. The degree of adaptability will be part of the quantitative performance of equitability.
- **Resilience**: as a factor of equitability, trustee in AN should return or fall back to the status which is without any bias or unfairness. The degree of resilience will be part of the quantitative performance of equitability.
- **Security**: as a factor of equitability, trustee in AN should achieve all the security concerns, and during which bias(es) or unfairness may occur some potential security problem(s) or issue(s). The degree of security will be part of the quantitative performance of equitability.

8.1.4 Factors of explanability

- **Interpretability**: as a factor of explanability, trustee in AN should express itself to be understood or accepted to people with varying degrees of expertise and capabilities including the public. The degree of interpretability will be part of the quantitative performance of explanability.
- **Accuracy**: as a factor of explanability, trustee in AN should explain itself with understandable and accurate way. The degree of accuracy will be part of the quantitative performance of explanability.
- **Security**: as a factor of explanability, trustee in AN should explain itself with safe way, i.e. maintain and prevent harm or damage. The degree of security will be part of the quantitative performance of explanability.

8.1.5 Factors of robustness

- **Security**: as a factor of robustness, trustee in AN should be safe enough and security guarantee. The degree of security will be part of the quantitative performance of robustness.
- **Controllability**: as a factor of robustness, trustee in AN should be under control and able to be taken over at any time in any condition. The degree of controllability will be part of the quantitative performance of robustness.
- **Privacy**: as a factor of robustness, trustee in AN should maintain privacy, including but not limited to data privacy, personal privacy and privacy security. The degree of privacy will be part of the quantitative performance of robustness.
- **Controllability**: as a factor of robustness, trustee in AN should be able to under control and taken over if necessary, so that the intelligent and autonomous system can be regarded as robust. The degree of controllability will be part of the quantitative performance of robustness.
- **Performance**: as a factor of robustness, trustee in AN should be with good and fine performance. The degree of performance will be part of the quantitative performance of robustness.

8.1.6 Factors of safety

- **Security**: as a factor of safety, trustee in AN should achieve all the security considerations of relevant scenario(s) or use case(s). The degree of security will be part of the quantitative performance of safety.
- **Controllability**: as a factor of safety, trustee in AN should be always under control and can be taken over at any time in any condition. The degree of controllability will be part of the quantitative performance of safety.
- **Adaptability**: as a factor of safety, trustee in AN should be able to adapt to related environment(s) and scenario(s), of course including the potential threads. The degree of security will be part of the quantitative performance of safety.
- **Recency**: as a factor of safety, trustee in AN should act or react to the threat(s) or harm(s) in time and even within a certain time duration. The degree of recency will be part of the quantitative performance of safety.

8.2 Metrics based on the basic principles

In order to make TiAN measurable and quantifiable, metrics for TiAN evaluation are refined based on the five basic principles. Each of the five basic principles relates to different but relevant factors, as Figure 2 shows. The factors for the basic principle are refined to the metrics for TiAN evaluation, so that to make TiAN evaluation with valuable metrics based on the basic principles.

Basing on basic principles of trusted AN, metrics for TiAN evaluation are refined as following:

- **Accuracy**: the degree of correctness and rationality of action(s), reaction(s), feedback(s), or decisions, etc made by trustor in AN.
- **Stability**: the degree of fluctuation imposed by trustor in AN execution on network performance or service QoE.
- **Controllability**: the degree to which trustor in AN can support human intervention under any conditions.
- **Resilience**: the degree to which AN can automatically fallback and maintain an acceptable operating state from failures or abnormal events.
- **Interpretability**: the degree to which the autonomous mechanism of trustor in AN can do the self-explaining and be understood by human and the relevant processes, actions or decisions can be objectively explained or interpreted.
- **Adaptability**: the degree to which the autonomous mechanism of AN can maintain all the above metrics in various application scenarios or in different conditions.

Besides above listed metrics, in the practical TiAN evaluation, more other metric(s) may be considered according to the actual scenarios, evaluating conditions or also the relationship(s) between trustor and trustee, etc.

8.3 Relationship between basic principles of trusted AN and metrics for TiAN evaluation

The basic principles are the basic requirements and rules for trusted AN, they are described with abstract words, meanwhile, in order to judge whether the AN can be trusted or not, furthermore, how much or what's the degree it can be trusted, TiAN is come up to make trust itself measurable and quantifiable for AN. As the key intermediaries of TiAN evaluation, the metrics are supposed to be measured and calculated in their own dimensions respectively.

For different AN scenarios or use cases, only when all the basic principles are satisfied and the TiAN reaches certain requirement(s)/benchmark(s) can AN be trusted.

9 Sub-metrics of TiAN evaluation

9.1 Sub-metrics of relevant metrics

Editor's Note – In this clause, the sub-metric will be generic described for TiAN evaluation being possible and practical.

In Table 1, the followings are the general descriptions of sub-metrics for TiAN evaluation. In practical TiAN evaluation(s), it may take specific conditions into consideration to determine sub-metrics and metrics which to be evaluated/assessed, depending on the different evaluation scenario(s) or use case(s) with different requirement(s) from trustor in AN.

NOTE – Formulas in Table 1 are in generic, plainly initial and intuitive expressions for relevant sub-metrics, so that to get the points of sub-metric description directly.

Table 1 – Sub-metrics of relevant metrics for TiAN evaluation

Metric	Sub-metric	General description of sub-metric
Accuracy	**Reproducibility**	Interactions in which the trustee reproduces the process of execution by trustee(s) across various interactions with the trustor, i.e. interactions which the trustee reproduces the same process and the same result(s)/action(s)/decision(s)/etc., using the same parameter(s)/input(s)/method(s)/algorithm(s)/knowledge/etc. and other relevant conditions, in TiAN evaluation. $\frac{num\ of\ the\ same\ reproduced\ results\ with\ executions}{num\ of\ all\ reproduced\ results}$
	Precision	Interactions which the trustee produces precise result(s) during execution of the process(es)/step(s) by trustee(s), in TiAN evaluation. $\frac{number\ of\ interactions\ with\ accurate\ results}{total\ number\ of\ interactions}$
	Timeliness	Action(s)/reaction(s)/feedback(s)/decision(s) produced by the trustee within specific time duration for TiAN evaluation. $\frac{num\ of\ action(s) within\ the\ specified\ time\ duration}{total\ number\ of\ actions\ produced\ in\ the\ whole\ evalation}$ NOTE – Above formula should be specified with evaluating time duration for evaluation.
	Validity	The valid output(s) from the trustee, in TiAN evaluation. $\frac{num\ of\ interactions\ with\ effective/valid\ output}{total\ number\ of\ interactions}$ NOTE – Above formula should be specified with evaluating validity of output.
	Resource	Compliant resource of data, knowledge or relevant input, in TiAN evaluation. $\frac{compliant\ resource\ of\ data, knowledge\ and\ relevant\ input}{all\ the\ input\ data, knowledge\ and\ relevant\ resource}$
Stability	**Interruption**	Time duration during which interactions are interrupted throughout the TiAN evaluation. $\frac{time\ duration\ of\ interruption}{total\ time\ duration\ of\ executing\ process\ of\ trustee(s)}$
	Accident	Accidents throughout the whole TiAN evaluation. $\frac{num\ of\ accident(s)}{num\ of\ action(s)\ \&\ reaction(s)\ \&\ decision(s)\ \&\ feedback(s)}$ NOTE – "Accident" is the behaviour(s) or executive results which are unexpected and harmful.

Table 1 – Sub-metrics of relevant metrics for TiAN evaluation

Metric	Sub-metric	General description of sub-metric
	Maturity	Actual maturity level in an interaction vs. the highest maturity level, in TiAN evaluation. $\frac{actual\ maturity\ degree\ \ in\ an\ interaction}{highest\ maturity\ degree\ of\ this\ interaction}$ NOTE – The "actual maturity degree" could be non-integer or integer.
	Variability	Self-changes of trustee(s), i.e. self-changed interaction(s), in TiAN evaluation. $\frac{num\ of\ self\ changed\ interaction(s), reaction(s), decision(s)}{total\ num\ of\ interaction(s), reaction(s), decision(s)}$ NOTE – "Variability" is opposite/negative effect to stability.
Controllability	**Predictability**	Percentage of trustee(s)' decision(s)/action(s)/reaction(s)/feeback(s) which can be predicted by trustor or within the expect of trustor, in TiAN evaluation. $\frac{num\ of\ decision(s)/action(s)\ can\ be\ predicted\ or\ within\ expectation}{num\ of\ all\ decision(s)/action(s)}$
	Supervision	Time duration that trustee(s) can be supervised by trustor(s) in any situations or at any conditions throughout the TiAN evaluation. $\frac{time\ duration\ which\ trustee\ is\ on\ supervision}{evaluation\ time\ duration}$ $= \frac{evaluation\ time\ duration - duration\ trustee\ out\ of\ supervision}{evaluation\ time\ duration}$
	Taken-over	Steps of trustee(s)'s processing can be taken over by trustor(s) in any situations or at any conditions throughout the TiAN evaluation. $\frac{num\ of steps\ can\ be\ taken\ over}{total\ num\ of\ steps}$ $= \frac{total\ num\ of\ steps - num\ of steps\ cannot\ be\ taken\ over}{total\ num\ of\ steps}$
Resilience	**Backup**	Weighted score/value of the process milestone(s)' backup in TiAN evaluation: $\frac{\sum_{i=1}^{n} Weight_i \times (completion\ percentage\ of\ point_i\ backup)}{\sum_{i=1}^{n} Weight_i}$ $Weight_i$ is the weight of $point_i$, its value could be defined by trustor or the vendor/provider of AN.
	Fallback	Trustee(s) can fallback to the right backuped process milestone successfully when necessary, throughout the TiAN evaluation. $\frac{num\ of\ right\ fallbacks}{total\ num\ of\ fallbacks}$ NOTE – The condition(s) of "when necessary" should be cleared described or defined.
	Reset	Trustee(s) can be reset to the original status when necessary, throughout the TiAN evaluation. NOTE – The condition(s) of "when necessary" should be cleared described or defined.
Interpretability	**Transparency**	Trustee's visible or transparent steps in the processing, data handling, algorithm, etc during the TiAN evaluation. $\frac{num\ of\ visible\ or\ transparent\ steps}{num\ of\ total\ steps\ in\ the\ processing, data\ handling, algorithm, etc.}$
	Translatability	Trustee's steps in the processing, data handling, algorithm, etc which can be translated in some language (including machine-language or human-language), in TiAN evaluation. $\frac{num\ of\ translatable\ steps}{num\ of\ steps\ in\ the\ processing, data\ handling, algorithm, etc.}$

Table 1 – Sub-metrics of relevant metrics for TiAN evaluation

Metric	Sub-metric	General description of sub-metric
	Understandability	Trustee's understandable steps in the processing, data handling, algorithm, etc, in TiAN evaluation. $\frac{num\ of\ understandable\ steps}{num\ of\ steps\ in\ the\ processing, data\ handling, algorithm, etc.}$
	Explanation accuracy	Accurate/precise explanation(s) among all the explanation(s) from trustee(s), in TiAN evaluation. $\frac{accurate/precise\ explanation(s)}{all\ the\ explanations}$ NOTE – In the real system or commercial environment, the calculation way may be different and more complicated than the above formula.
	Explanation integrity	Explanation(s)' completeness in TiAN evaluation, the explanation(s) are recommended to cover the tasks including but not limited to execution, awareness, analysis, decisions and intent handling.
	Explanation reproducibility	Reproducible explanation(s) among all the explanation(s) from trustee(s), in TiAN evaluation. $\frac{reproducible\ explanation(s)}{all\ the\ explanations}$
Adaptability	**Flexibility**	Processing which can be changed by the trustee(s) without impacting the ability of the trustee to satisfy the relevant and specific requirement(s), during TiAN evaluation.
	Adjustment	Processing which has been changed during TiAN evaluation, but the decision(s)/action(s)/reaction(s)/feeback(s) can still satisfy the requirements of related scenario or use case.

NOTE – In above table, "trustee" represents "tustee in AN", in the meantime, "trustor" represents "trustor in AN".

In practical TiAN evaluations, evaluation methods, methodologies, sub-metric(s) and metric(s) to be assessed, weight(s) of calculation(s) etc are supposed to be customized depending on the inputs, parameters, environment, trustee in AN, demand(s) and requirement(s) from trustor in AN, etc for different scenario(s) or use case(s).

Considering the unities of sub-metric(s) and metric(s), it is necessary to keep the same unified ways for both sub-metric(s) and metric(s), it can be percentage and it can also be some other units which can finely express evaluation results, and of course, other ways if appropriate.

9.2 Evaluation methodology of sub-metrics for TiAN evaluation

Editor's Note – In this clause, method of sub-metric assessing will be described in general, so that, the methodology can be widely used and guide the practical TiAN evaluation.

In order to make TiAN measurable and quantifiable, firstly, the basic principles have been described for a trusted AN. Basing on the basic principles of trusted AN, metrics have been derived and further explained, followed by metrics, and sub-metrics which relates to each metrics that have been listed and described generally in Table 1 above. In order to make TiAN evaluation practical, Table 2 discusses and describes the evaluation methodology of all the sub-metrics in general. In practical TiAN evaluation, the relevant methods of sub-metrics evaluation will be specific described or ruled basing on following methodologies, and of course considering the actual situation(s).

Table 2 – Sub-metric's evaluation methodology

Metric	Sub-metric	Evaluation methodology
Accuracy	**Reproducibility**	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Integrity of reproducing results, i.e. the essential/necessary aspects of the intelligent/autonomous process/entity/algorithm/etc. • Correctness of reproducing results, i.e. the same results with executed ones. • Consistency of reproducing results, i.e. reproducing results are supposed to be consistent no matter how many times of reproducing. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc, and also the requirement(s) from trustor in AN.
	Precision	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Correctness of executive result(s). • Deviation within tolerance and out of tolerance. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Timeliness	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Time cost of action(s), reaction(s), feedback(s) or decision(s), etc. by trustee. • Time duration of the whole executive process. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Validity	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Availability of output from trustee, e.g. action(s), reaction(s), feedback(s) or decision(s), etc. by trustee. • Useless of output from trustee, e.g. action(s), reaction(s), feedback(s) or decision(s), etc. by trustee. • Falsity output from trustee, e.g. action(s), reaction(s), feedback(s) or decision(s), etc. by trustee. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
Stability	**Interruption**	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Times of all the interruption(s). • Frequency of interruption. • Time duration of each interruption. • Average time duration of all the interruption(s). • Total time duration of all the interruption(s). The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.

Table 2 – Sub-metric's evaluation methodology

Metric	Sub-metric	Evaluation methodology
	Accident	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Times of all the accident(s). • Frequency of accident(s). • Time duration of each accident(s). • Loss of all the accident(s). The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Maturity	For intelligent and autonomous system/solution, there are maturity evaluation standard(s) or specification(s) already, the maturity evaluation methods can be referred to the related document(s) basing on the scenarios or use cases.
	Variability	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Times of sudden-changes/transilience. • Negative effects of sudden-changes/transilience. • Positive effects of sudden-changes/transilience. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
Controllability	**Predictability**	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Action(s), reaction(s), feedback(s) or decision(s) etc. within prediction. • Action(s), reaction(s), feedback(s) or decision(s) etc. out of prediction. • Negative effects of Action(s), reaction(s), feedback(s) or decision(s) etc. out of prediction. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Supervision	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • The process(es) under supervised. • The process(es) cannot under supervised. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Taken-over	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • The process(es) can be taken over at anytime in any condition(s). • The process(es) can be taken over at certain time in certain condition(s). • The process(es) cannot be taken over at certain time in certain condition(s). • The process(es) cannot be taken over at anytime in any condition. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.

Table 2 – Sub-metric's evaluation methodology

Metric	Sub-metric	Evaluation methodology
Resilience	**Backup**	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Setting of key point(s) which need to be backup. • Quality of backup, including integrity, reliability, security, etc. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Fallback	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • The ability of fallback at anytime in any condition if necessary. • Fallback to right point which is backup already. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Reset	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • The ability of reset at anytime in any condition if necessary. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
Interpretability	**Transparency**	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Visible process(es), data, program(s), etc. • White-box like process. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Translatability	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Completely translatable explanation(s). • Partly translatable explanation(s). The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Understandability	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Explanation(s) can be understood by specialist. • Explanation(s) can be understood by expert with certain degree of expertise. • Explanation(s) can be understood by general. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Explanation accuracy	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Correct explanation(s) among all the explanation(s). • Useless explanation(s) among all the explanation(s). • Wrong explanation(s) among all the explanation(s). The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.

Table 2 – Sub-metric's evaluation methodology

Metric	Sub-metric	Evaluation methodology
	Explanation integrity	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Aspect(s) which the explanation(s) covered. • Element(s) which the explanation(s) supposed to include. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Reproducible explanation	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Explanation(s) need to be reproduced. • Explanation(s) can be reproduced. • Explanation(s) can not be reproduced. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
Adaptability	**Flexibility**	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Negative effects by environment and human factor(s). • Adaptability to the environment and human influence. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.
	Adjustment	It can be assessed with scoring manually and also can be assessed automatically with algorithm with following aspects: • Adjustment to the change of environment and even the configurations etc. The practical evaluation/assessment can further detailed and refine depending on relevant scenarios, use case, practical parameters, etc., and also the requirement(s) from trustor in AN.

10 TiAN calculation methods

10.1 General quantitative calculations of TiAN evaluation

10.1.1 Calculation from sub-metric(s) to metric(s)

The sub-metric(s) are supposed to be scored manually or automatically by an algorithm. The sub-metric(s) in Table 2 above which needs to be assessed will depend on relevant and specific scenario, use case, and also the initial setting(s)/requirement(s)/demand(s) of trustor in AN. The assessed quantitative result(s) of sub-metric(s) will applied to calculate corresponding metric with some quantitative calculation which is generally shown as below:

$$Value\ of\ Metric_i = \sum_{j=0}^{m} [weight_j \times (value\ of\ submetric_j)]\,, \qquad \sum_{j=0}^{m} weight_j = 1$$

In above calculation of $Value\ of\ Metric_i$, $Weight_j$ will depend on relevant scenario, use case, environment, settings of trustor in AN, etc.

10.1.2 Calculation from sub-metric(s) to metric(s)

Editor's Note – In this clause, the sub-metric will be generic described for TiAN evaluation being possible and practical.

After metric(s) calculation, the TiAN value can be calculated from value(s) of metric(s), and the following is the generic calculation:

$$TiAN\ value = \sum_{i=0}^{n}(weight_i \times metric_i), \qquad \sum_{i=0}^{n} weight_i = 1$$

In above calculation of $TiAN\ value$, $Weight_i$ will depend on scenario, use case, environment, settings of trustor in AN, etc.

10.2 Quantitative ways for TiAN

TiAN quantitative result(s) will depend on the requirements of trustor in AN or the demand(s) of actual judgement, quantitative result(s) of TiAN can be in binary, coarse-grained, fine-grained, semantic-level, and other ways. Below are some typical quantitative options of TiAN for reference.

10.2.1 Binary

In order to directly make judgement(s), TiAN can be set or required to be in binary. The advantages will be on convenience and direct for trustor in AN to make decision(s) and judgement(s), i.e. whether to trust or not, but the disadvantage will be that, it may be impossible or hard for trustor in AN to make detailed analysis and consideration depending on TiAN.

Followings are some possible binary ways of TiAN:

- "0" or "1": the traditional and original ways of computer language, "0" should be untrust and "1" should be trusted.
- "untrust" or "trust": the most directly expression ways of TiAN, in which it can make judgement directly and literally.

10.2.2 Coarse-grained

As discussed before, trustor in AN makes the authorization(s) not only depending on TiAN but will also consider other factors including but not limit to actual application, subjective considerations, QoE, etc. The finer the evaluation of TiAN, the more accurate of decision(s) will trustor in AN make.

Followings are some possible coarse-grained ways of TiAN:

- Levels: some rough level forms, e.g. "Level 0" to "Level 5", which divide the TiAN into a series of levels. With levels, TiAN will be divided into some different degrees/levels, for trustor in AN it can make further considerations depending on this level result(s).
- Rough scores: just similar to level ways, it can also be some rough scores, e.g. "0" to "9", depending on that trustor in AN can make further considerations before decision or authorization.
- General trust degrees: also it can be trust degrees of the generic represent/express of TiAN, e.g. "fully trust", "highly trust", "tend to trust", "tend to distrust", "highly distrust" and "fully distrust", which express TiAN with wording.

10.2.3 Fine-grained

In order to make TiAN more detailed and refined, there are also some fine-grained ways for TiAN calculation. With fine-grain TiAN calculation, further analysis can be done and the decision(s)/authorization(s) can be also more elaborate.

Following are some possible fine-grain ways of TiAN:

- Percentage: expressing with percentage, e.g. 0% to 100%.
- Elaborate score: scores which are elaborate and more detailed, e.g. 0 to 99.

Based on above, fine-grained ways are more appropriate as TiAN quantitative ways, with which, trustor in AN can make further and more detailed considerations depending on TiAN, i.e. with fine-grained TiAN the objective part of trust can be much more accurate for trustor in AN to take into considerations and the relevant analysis.

10.3 Comparison of TiAN

As the important reference for trustor in AN to make analysis, judgement(s), decision(s), etc., TiAN can be evaluated and used in most of the autonomous or intelligent scenario(s) and use case(s) of AN. However, the comparison(s) of TiAN values is applicable only in case of the same evaluation environment, scenario or use case, because only in the same conditions for TiAN evaluation can it be meaningful to make TiAN comparison(s) and even the following analysis, judgement(s) or decision(s), etc.

Appendix I

Typical scenarios of TiAN evaluation

Editor's Note – This appendix describes the typical TiAN evaluation scenarios to make clear proposals to TiAN evaluation practice.

I.1 Network and service planning

Network and service planning is the processes of designing and delivering new or enhanced network or service based on the business, market, product and customer service requirements. In AN, network and service planning may autonomously process to design and deliver new or enhanced network or service, and during which TiAN evaluation is necessary for trustor in AN to make judgement(s)/analysis/decision(s)/etc. Following are key items which need to be considered before TiAN evaluation for autonomous network and service planning:

- The identities:
  - Trustor in AN: network and service planning authorizer, i.e. authorizer of autonomous network and service design or deliver
  - Trustee in AN: autonomous network and service entity, process or component for planning, which includes but not limit to autonomous network and service initial design or enhancement.
- Metrics and sub-metrics for TiAN evaluation:

Table 3 below list the metrics of TiAN evaluation in autonomous network and service planning, and related sub-metrics to be assessed.

Table 3 – Metrics and sub-metrics for TiAN evaluation of network and service planning

Metric	Sub-metric
Accuracy	Reproducibility
	Precision
	Timeliness
Stability	Interruption
	Maturity
	Variability
Controllability	Predictability
Adaptability	Flexibility
	Adjustment

- TiAN evaluation methodology for network and service planning:
  - Firstly, trustor in AN triggers TiAN evaluation before authorization of autonomous planning. Continuous triggers can be set periodically or aperiodically to trustee in AN depending on the actual requirement(s) and need(s).
  - Each of the sub-metrics in Table 3 above can be assessed manually and also automatically with an algorithm. Before that, the unit and unified ways of all the sub-metrics should be defined and confirmed, along with that, the weights of each sub-metrics and metrics are necessary to be set down to do the following calculating.
  - Calculations from sub-metrics to metrics:

$$Accuracy_{planning} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Reproducibiliy} \times Reproducibility_{planning} + weight_{Precision} \times Precision_{planning} + weight_{Timeliness} \times Timeliness_{planning}$$

($weight_{Reproducibiliy} + weight_{Precision} + weight_{Timeliness} = 1$, if there is no further specific requirement, it can be set as $weight_{Reproducibiliy} = weight_{Precision} = weight_{Timeliness} = \frac{1}{3}$)

$$Stability_{planning} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Interruption} \times Interruption_{planning} + weight_{Maturity} \times Maturity_{planning} + weight_{Variability} \times Variability_{planning}$$

($weight_{Interruption} + weight_{Maturity} + weight_{Variability} = 1$, if there is no further specific requirement, it can be set as $weight_{Interruption} = weight_{Maturity} = weight_{Variability} = \frac{1}{3}$)

$$Adaptability_{planning} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Flexibility} \times Flexibility_{planning} + weight_{Adjustment} \times Adjustment_{planning}$$

($weight_{Flexibility} + weight_{Adjustment} = 1$, if there is no further specific requirement, it can be set as $weight_{Flexibility} = weight_{Adjustment} = \frac{1}{2}$)

– Calculation of TiAN in autonomous network and service planning:

$$TiAN_{planning} = \sum_{i=0}^{n}(weight_i \times metric_i)$$
$$= weight_{Accuracy} \times Accuracy_{planning} + weight_{Stability} \times Stability_{planning} + weight_{Controllability} \times Controllability_{planning} + weight_{Adaptability} \times Adaptability_{planning}$$

($weight_{Accuracy} + weight_{Stability} + weight_{Controllability} + weight_{Adaptability} = 1$, if there is no further specific requirement, it can be set as $weight_{Accuracy} = weight_{Stability} = weight_{Controllability} = weight_{Adaptability} = \frac{1}{4}$)

• Requirements for network and service planning:

In order to get trust from trustor in AN, in other words, in order to be trusted, trustee in AN in network and service planning scenario is supposed to obtain following requirements:

– Planning-Req-001: it is required that, autonomous planning cannot violate the requirement(s) of business, market, product or customer service, etc.

I.2 Network and service deployment

Network and service deployment is the process(es) of allocation, installation, configuration, activation and verification of specific network and service. In AN, network and service deployment may autonomously process to allocate, install, configure, activate and verify of specific network and service, and during which TiAN evaluation is necessary for trustor in AN to make judgement(s)/analysis/decision(s)/etc. Following are key items that need to be considered before TiAN evaluation for autonomous network and service deployment:

• The identities:

– Trustor in AN: network and service deployment authorizer, i.e. authorizer of specific autonomous network and service allocation, installation, configuration, activation or verification.

– Trustee in AN: autonomous network and service entity, process or component for deployment, which includes but not limit to autonomous network and service allocation, installation, configuration, activation and verification, etc.

- Metrics and sub-metrics for evaluation:

Following Table 4 has listed the metrics of TiAN evaluation in network and service deployment, and related sub-metrics to be assessed.

Table 4 – Metrics and sub-metrics for TiAN evaluation of network and service deployment

Metric	Sub-metric
Accuracy	Reproducibility
	Precision
	Timeliness
	Validity
Stability	Interruption
	Accident
	Maturity
	Variability
Controllability	Predictability
	Supervision
Resilience	Backup
	Fallback
	Reset
Interpretability	Transparency
	Translatability
	Understandability
Adaptability	Flexibility
	Adjustment

- Evaluation methodology for network and service deployment:
  - Firstly, trustor in AN triggers TiAN evaluation before authorization of autonomous deployment, continuous triggers can be set periodically or aperiodically to trustee in AN depending on the actual requirement(s) and need(s).
  - Each of the sub-metrics in Table 4 can be assessed manually and also automatically with an algorithm. Before that, the unit and unified ways of all the sub-metrics should be defined and confirmed, alongside the weights of each sub-metrics, and metrics are necessary to be set down for the following calculations.
  - Calculations from sub-metrics to metrics:

$$Accuracy_{deployment} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Reproducibiliy} \times Reproducibility_{deployment} + weight_{Precision} \times Precision_{deployment} + weight_{Timeliness} \times Timeliness_{deployment} + weight_{Validity} \times Timeliness_{deployment}$$

($weight_{Reproducibiliy} + weight_{Precision} + weight_{Timeliness} + weight_{Validity} = 1$, if there is no further specific requirement, it can be set as $weight_{Reproducibiliy} = weight_{Precision} = weight_{Timeliness} = weight_{Validity} = \frac{1}{4}$)

$$Stability_{deployment} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Interruption} \times Interruption_{deployment} + weight_{Accident} \times Accident_{deployment}$$
$$+ weight_{Maturity} \times Maturity_{deployment} + weight_{Variability} \times Variability_{deployment}$$

($weight_{Interruption} + weight_{Accident} + weight_{Maturity} + weight_{Variability} = 1$, if there is no further specific requirement, it can be set as $weight_{Interruption} = weight_{Accident} = weight_{Maturity} = weight_{Variability} = \frac{1}{4}$)

$$Controllability_{deployment} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Predictability} \times Predictability_{deployment}$$
$$+ weight_{Supervision} \times Supervision_{deployment}$$

($weight_{Predictability} + weight_{Supervision} = 1$, if there is no further specific requirement, it can be set as $weight_{Predictability} + weight_{Supervision} = \frac{1}{2}$)

$$Resilience_{deployment} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{backup} \times Backup_{deployment} + weight_{Fallback} \times Fallback_{deployment}$$
$$+ weight_{Reset} \times Maturity_{deployment}$$

($weight_{backup} + weight_{Fallback} + weight_{Reset} = 1$, if there is no further specific requirement, it can be set as $weight_{backup} = weight_{Fallback} = weight_{Reset} = \frac{1}{3}$)

$$Interpretability_{deployment} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Transparency} \times Transparency_{deployment}$$
$$+ weight_{Translatability} \times Translatability_{deployment}$$
$$+ weight_{Understandability} \times Understandability_{deployment}$$

($weight_{backup} + weight_{Fallback} + weight_{Reset} = 1$, if there is no further specific requirement, it can be set as $weight_{backup} = weight_{Fallback} = weight_{Reset} = \frac{1}{3}$)

$$Adaptability_{planning} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Flexibility} \times Flexibility_{deployment} + weight_{Adjustment} \times Adjustment_{deployment}$$

($weight_{Flexibility} + weight_{Adjustment} = 1$, if there is no further specific requirement, it can be set as $weight_{Flexibility} = weight_{Adjustment} = \frac{1}{2}$)

– Calculation of TiAN in autonomous network and service planning:

$$TiAN_{deployment} = \sum_{i=0}^{n}(weight_i \times metric_i)$$
$$= weight_{Accuracy} \times Accuracy_{deployment} + weight_{Stability} \times Stability_{deployment}$$
$$+ weight_{Controllability} \times Controllability_{deploymnet} + weight_{Resilience} \times Resilience_{deploymnet}$$
$$+ weight_{Interpretability} \times Interpretability_{deploymnet} + weight_{Adaptability}$$
$$\times Adaptability_{deployment}$$

($weight_{Accuracy} + weight_{Stability} + weight_{Controllability} + weight_{Resilience} + weight_{Interpretability} + weight_{Adaptability} = 1$, if there is no further specific requirement, it can be set as $weight_{Accuracy} = weight_{Stability} = weight_{Controllability} = weight_{Resilience} = weight_{Interpretability} = weight_{Adaptability} = \frac{1}{6}$)

- Requirements for network and service deployment:
  - Deployment-Req-001: it is required that, autonomous deployment cannot destroy existing facilities.
  - Deployment-Req-002: it is required that, autonomous deployment should base on the existing infrastructures deployment.

I.3 Network and service maintenance

Network and service maintenance is the process of monitoring, analyzing and healing of the network and service issue(s). In AN, network and service maintenance may autonomously process to monitor, analyse and heal the network or service issue(s), and during which, TiAN evaluation is necessary for trustor in AN to make judgement(s)/analysis/decision(s)/etc. Followings are key items which need to be considered before TiAN evaluation for autonomous network and service maintenance:

- The identities:
  - Trustor in AN: network and service maintenance authorizer, i.e. authorizer of specific autonomous network and service monitoring, analysis and healing.
  - Trustee in AN: autonomous network and service entity, process or component for maintenance, which includes but not limit to autonomous network and service monitor, analyse and heal, etc.
- Metrics and sub-metrics for evaluation:

Table 5 below lists the metrics of TiAN evaluation in network and service maintenance, and related sub-metrics to be assessed.

Table 5 – Metrics and sub-metrics for TiAN evaluation of network and service maintenance

Metric	Sub-metric
Accuracy	Reproducibility
	Timeliness
Stability	Interruption
	Accident
	Maturity
	Variability
Controllability	Predictability
	Supervision
	Taken-over
Resilience	Backup
	Fallback
	Reset
Adaptability	Flexibility
	Adjustment

- Evaluation methodology for network and service maintenance:
  - Firstly, trustor in AN triggers TiAN evaluation before authorization of autonomous maintenance, continuous triggers can be set periodically or aperiodically to trustee in AN depending on the actual requirement(s) and need(s).

– Each of the sub-metrics in above Table 5 can be assessed manually and also automatically with an algorithm. Before that, the unit and unified ways of all the sub-metrics should be defined and confirmed, along with that, the weights of each sub-metrics and metrics are necessary to be set down to do the following calculations.

– Calculations from sub-metrics to metrics:

$$Accuracy_{maintenance} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Reproducibiliy} \times Reproducibility_{maintenance} + weight_{Timeliness} \times Timeliness_{maintenance}$$

($weight_{Reproducibiliy} + weight_{Timeliness} = 1$, if there is no further specific requirement, it can be set as $weight_{Reproducibiliy} = weight_{Timeliness} = \frac{1}{2}$)

$$Stability_{maintenance} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Interruption} \times Interruption_{maintenance} + weight_{Accident} \times Accident_{maintenance} + weight_{Maturity} \times Maturity_{maintenance} + weight_{Variability} \times Variability_{maintenance}$$

($weight_{Interruption} + weight_{Accident} + weight_{Maturity} + weight_{Variability} = 1$, if there is no further specific requirement, it can be set as $weight_{Interruption} = weight_{Maturity} = weight_{Accident} = weight_{Variability} = \frac{1}{4}$)

$$Controllability_{maintenance} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Predictability} \times Predictability_{maintenance} + weight_{Supervision} \times Supervision_{maintenance} + weight_{Taken-over} \times Taken-over_{maintenance}$$

($weight_{Predictability} + weight_{Supervision} + weight_{Taken-over} = 1$, if there is no further specific requirement, it can be set as $weight_{Predictability} = weight_{Supervision} = weight_{Taken-over} = \frac{1}{3}$)

$$Resilience_{maintenance} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Backup} \times Backup_{maintenance} + weight_{Fallback} \times Fallback_{maintenance} + weight_{Reset} \times Reset_{maintenance}$$

($weight_{Backup} + weight_{Fallback} + weight_{Reset} = 1$, if there is no further specific requirement, it can be set as $weight_{Backup} = weight_{Fallback} = weight_{Reset} = \frac{1}{3}$)

$$Adaptability_{maintenance} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Flexibility} \times Flexibility_{maintenance} + weight_{Adjustment} \times Adjustment_{maintenance}$$

($weight_{Flexibility} + weight_{Adjustment} = 1$, if there is no further specific requirement, it can be set as $weight_{Flexibility} = weight_{Adjustment} = \frac{1}{2}$)

– Calculation of TiAN in autonomous network and service planning:

$$TiAN_{maintenance} = \sum_{i=0}^{n}(weight_i \times metric_i)$$
$$= weight_{Accuracy} \times Accuracy_{maintenance} + weight_{Stability} \times Stability_{maintenance} + weight_{Controllability} \times Controllability_{maintenance} + weight_{Resilience} \times Resilience_{maintenance} + weight_{Interpretability} \times Interpretability_{maintenance} + weight_{Adaptability} \times Adaptability_{maintenance}$$

($weight_{Accuracy} + weight_{Stability} + weight_{Controllability} + weight_{Resilience} + weight_{Interpretability} + weight_{Adaptability} = 1$, if there is no further specific requirement, it can be set as $weight_{Accuracy} = weight_{Stability} = weight_{Controllability} = weight_{Resilience} = weight_{Interpretability} = weight_{Adaptability} = \frac{1}{6}$)

- Requirements for network and service maintenance:
  - Maintenance-Req-001: it is required that, autonomous maintenance cannot interrupt, damage or erode other network function(s) or block(s).
  - Maintenance-Req-002: it is required that, autonomous maintenance should be within the compliance including inner policies, legal, etc.

I.4 Network and service optimization

Network and service optimization is the process of monitoring, analyzing and optimization/assurance of the network and service performance. In AN, network and service optimization may autonomously process to monitor, analyse or optimization/assurance of the performance, and during which, TiAN evaluation is necessary for trustor in AN to make judgement(s)/analysis/decision(s)/etc. Followings are key items which need to be considered before TiAN evaluation for autonomous network and service optimization:

- The identities:
  - Trustor in AN: network and service optimization authorizer, i.e. authorizer of specific autonomous network and service performance monitoring, analysis or optimization/assurance.
  - Trustee in AN: autonomous network and service entity, process or component for performance optimization, which includes but not limit to autonomous network and service performance monitoring, analysis or optimization/assurance etc.
- Metrics and sub-metrics for evaluation:

Table 6 lists the metrics of TiAN evaluation in network and service optimization, and related sub-metrics to be assessed.

Table 6 – Metrics and sub-metrics for TiAN evaluation of network and service optimization

Metric	Sub-metric
Accuracy	Reproducibility
	Timeliness
Stability	Interruption
	Maturity
Controllability	Predictability
	Supervision
	Taken-over
Resilience	Backup
	Fallback
	Reset
Interpretability	Transparency
	Translatability
	Understandability
Adaptability	Flexibility
	Adjustment

- Evaluation methodology for network and service optimization:
  - Firstly, trustor in AN triggers TiAN evaluation before authorization of autonomous optimization, continuous triggers can be set periodically or aperiodically to trustee in AN depending on the actual requirement(s) and need(s).
  - Each of the sub-metrics in above Table 6 can be assessed manually and also autonomously with algorithm. Before that, the unit and unified ways of all the sub-metrics should be defined and confirmed, along with that, the weights of each sub-metrics and metrics are necessary to be set down to do the following calculating.
  - Calculations from sub-metrics to metrics:

$$Accuracy_{optimization} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Reproducibiliy} \times Reproducibility_{optimization} + weight_{Timeliness} \times Timeliness_{optimization}$$

($weight_{Reproducibiliy} + weight_{Timeliness} = 1$, if there is no further specific requirement, it can be set as $weight_{Reproducibiliy} = weight_{Timeliness} = \frac{1}{2}$)

$$Stability_{optimization} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Interruption} \times Interruption_{optimization} + weight_{Maturity} \times Maturity_{optimization}$$

($weight_{Interruption} + weight_{Maturity} = 1$, if there is no further specific requirement, it can be set as $weight_{Interruption} = weight_{Maturity} = \frac{1}{2}$)

$$Controllability_{maintenance} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Predictability} \times Predictability_{optimization} + weight_{Supervision} \times Supervision_{optimization} + weight_{Taken-over} \times Taken-over_{optimization}$$

($weight_{Predictability} + weight_{Supervision} + weight_{Taken-over} = 1$, if there is no further specific requirement, it can be set as $weight_{Predictability} = weight_{Supervision} = weight_{Taken-over} = \frac{1}{3}$)

$$Resilience_{optimization} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Backup} \times Backup_{optimization} + weight_{Fallback} \times Fallback_{optimization} + weight_{Reset} \times Reset_{optimization}$$

($weight_{Backup} + weight_{Fallback} + weight_{Reset} = 1$, if there is no further specific requirement, it can be set as $weight_{Backup} = weight_{Fallback} = weight_{Reset} = \frac{1}{3}$)

$$Adaptability_{optimization} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Flexibility} \times Flexibility_{optimization} + weight_{Adjustment} \times Adjustment_{optimization}$$

($weight_{Flexibility} + weight_{Adjustment} = 1$, if there is no further specific requirement, it can be set as $weight_{Flexibility} = weight_{Adjustment} = \frac{1}{2}$)

– Calculation of TiAN in autonomous network and service planning:

$$TiAN_{optimization} = \sum_{i=0}^{n}(weight_i \times metric_i)$$
$$= weight_{Accuracy} \times Accuracy_{optimization} + weight_{Stability} \times Stability_{optimization}$$
$$+ weight_{Controllability} \times Controllability_{optimization}$$
$$+ weight_{Resilience} \times Resilience_{optimization}$$
$$+ weight_{Interpretability} \times Interpretability_{optimization}$$
$$+ weight_{Adaptability} \times Adaptability_{optimization}$$

($weight_{Accuracy} + weight_{Stability} + weight_{Controllability} + weight_{Resilience} + weight_{Interpretability} + weight_{Adaptability} = 1$, if there is no further specific requirement, it can be set as $weight_{Accuracy} = weight_{Stability} = weight_{Controllability} = weight_{Resilience} = weight_{Interpretability} = weight_{Adaptability} = \frac{1}{6}$)

- Requirements for network and service optimization:
  - Optimization-Req-001: it is required that, autonomous optimization cannot interrupt, damage or erode other network function(s) or block(s).
  - Optimization-Req-002: it is required that, autonomous optimization should maintain and ensure security concerns.

I.5 Network and service operation

Network and service operation is the process of network and service configuration depending on customer's requirements, service assurance and monitoring so that to timely discover related problem(s) and quickly respond. In AN, network and service operation may autonomously process to configure network or service, and during which, TiAN evaluation is necessary for trustor in AN to make judgement(s)/analysis/decision(s)/etc. Followings are key items which need to be considered before TiAN evaluation for autonomous network and service operation:

- The identities:
  - Trustor in AN: network and service operation authorizer, i.e. authorizer of specific autonomous network and service configuring which is usually depending on customer's requirements, service assurance and monitoring.
  - Trustee in AN: autonomous network and service entity, process or component for performance operation, which includes but not limit to autonomous network and service configuring which is usually depending on customer's requirements, service assurance and monitoring, etc.
- Metrics and sub-metrics for evaluation:

Following Table 7 has listed the metrics of TiAN evaluation in network and service operation, and related sub-metrics to be assessed.

Table 7 – Metrics and sub-metrics for TiAN evaluation of network and service operation

Metric	Sub-metric
Accuracy	Reproducibility
	Precision
	Timeliness
Stability	Interruption
	Accident
	Maturity
	Variability

Table 7 – Metrics and sub-metrics for TiAN evaluation of network and service operation

Metric	Sub-metric
Controllability	Predictability
	Supervision
	Taken-over
Resilience	Backup
	Fallback
	Reset
Interpretability	Transparency
	Translatability
Adaptability	Flexibility
	Adjustment

- Evaluation methodology for network and service operation:
  - Firstly, trustor in AN triggers TiAN evaluation before authorization of autonomous optimization, continuous triggers can be set periodically or aperiodically to trustee in AN depending on the actual requirement(s) and need(s).
  - Each of the sub-metrics in above Table 7 can be assessed manually and also autonomously with algorithm. Before that, the unit and unified ways of all the sub-metrics should be defined and confirmed, along with that, the weights of each sub-metrics and metrics are necessary to be set down to do the following calculating.
  - Calculations from sub-metrics to metrics:

$$Accuracy_{operation} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Reproducibiliy} \times Reproducibility_{operation} + weight_{Precision} \times Precision_{operation} + weight_{Timeliness} \times Timeliness_{operation}$$

($weight_{Reproducibiliy} + weight_{Precision} + weight_{Timeliness} = 1$, if there is no further specific requirement, it can be set as $weight_{Reproducibiliy} = weight_{Precision} = weight_{Timeliness} = \frac{1}{3}$)

$$Stability_{operation} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Interruption} \times Interruption_{operation} + weight_{Accident} \times Accident_{operation} + weight_{Maturity} \times Maturity_{operation} + weight_{Variability} \times Variability_{operation}$$

($weight_{Interruption} + weight_{Accident} + weight_{Maturity} + weight_{Variability} = 1$, if there is no further specific requirement, it can be set as $weight_{Interruption} = weight_{Accident} = weight_{Maturity} = weight_{Variability} = \frac{1}{4}$)

$$Controllability_{operation} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Predictability} \times Predictability_{optimization} + weight_{Supervision} \times Supervision_{operation} + weight_{Taken-over} \times Taken-over_{operation}$$

($weight_{Predictability} + weight_{Supervision} + weight_{Taken-over} = 1$, if there is no further specific requirement, it can be set as $weight_{Predictability} = weight_{Supervision} = weight_{Taken-over} = \frac{1}{3}$)

$$Resilience_{optimization} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Backup} \times Backup_{operation} + weight_{Fallback} \times Fallback_{operation} + weight_{Reset} \times Reset_{operation}$$

($weight_{Backup} + weight_{Fallback} + weight_{Reset} = 1$, if there is no further specific requirement, it can be set as $weight_{Backup} = weight_{Fallback} = weight_{Reset} = \frac{1}{3}$)

$$Adaptability_{operation} = \sum_{j=0}^{m}[weight_j \times (value\ of\ submetric_j)]$$
$$= weight_{Flexibility} \times Flexibility_{operation} + weight_{Adjustment} \times Adjustment_{operation}$$

($weight_{Flexibility} + weight_{Adjustment} = 1$, if there is no further specific requirement, it can be set as $weight_{Flexibility} = weight_{Adjustment} = \frac{1}{2}$)

– Calculation of TiAN in autonomous network and service planning:

$$TiAN_{operation} = \sum_{i=0}^{n}(weight_i \times metric_i)$$
$$= weight_{Accuracy} \times Accuracy_{operation} + weight_{Stability} \times Stability_{operation} + weight_{Controllability} \times Controllability_{operation} + weight_{Resilience} \times Resilience_{operation} + weight_{Interpretability} \times Interpretability_{operation} + weight_{Adaptability} \times Adaptability_{operation}$$

($weight_{Accuracy} + weight_{Stability} + weight_{Controllability} + weight_{Resilience} + weight_{Interpretability} + weight_{Adaptability} = 1$, if there is no further specific requirement, it can be set as $weight_{Accuracy} = weight_{Stability} = weight_{Controllability} = weight_{Resilience} = weight_{Interpretability} = weight_{Adaptability} = \frac{1}{6}$)

- Requirements for network and service operation:
  – Operation-Req-001: it is required that, autonomous operation should keep performance.

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