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SERIES Q: SWITCHING AND SIGNALLING, AND ASSOCIATED MEASUREMENTS AND TESTS

Testing specifications – Testing specifications for IMT-2020 and IoT

Framework of model network for tactile Internet testing

Recommendation ITU-T Q.4065

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Recommendation ITU-T Q.4065

Framework of model network for tactile Internet testing

Summary

According to *ITU-T Technology Watch Report, The Tactile Internet* (2014), the character of the tactile Internet is defined as extremely low latency in combination with high availability, reliability and security.

The existing telecommunication networks are mainly developed for distributing traditional voice, video and data services which parameters do not require extremely low latency.

The services which are based on tactile Internet will require establishing new principles of data processing in current and future networks. Currently, most existing telecommunication networks do not allow operators to scale tactile Internet services and provide it to most of their customers.

In this regard, a model network may become an operator's tool aimed at testing the tactile Internet services before the implementation on the live telecommunication network.

Recommendation ITU-T Q.4065 describes the architecture, scenarios, and key networks metrics for establishing model network for testing tactile Internet services. Specifically, the aim of a model network is to study the general principles of data generation for transmission of a tactile sensation through the telecommunication networks, including analysis of the network latency and other network performance parameters.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Q.4065	2021-05-14	11	11.1002/1000/14617

Keywords

Model network, tactile Internet, testing.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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1 Scope

This Recommendation describes an architecture, scenarios, and key network metrics for establishing a model network for testing tactile Internet services.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.671] Recommendation ITU-T G.671 (2019), *Transmission characteristics of optical components and subsystems*.

[ITU-T Q.3901] Recommendation ITU-T Q.3901 (2008), *Testing topology for networks and services based on NGN technical means*.

[ITU-T Y.1540] Recommendation ITU-T Y.1540 (2019), *Internet protocol data communication service – IP packet transfer and availability performance parameters*.

[ITU-T Y.3300] Recommendation ITU-T Y.3300 (2014), *Framework of software-defined networking*.

3 Definition

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 tactile Internet [b-ITU-T TWR TI]: A concept on the Internet evolution that purports to bring a new dimension into the human-to-machine and human-to-human interactions by enabling haptic sensations. The main network characteristic of tactile Internet is an extremely low latency in combination with high availability, reliability and security.

3.1.2 software-defined networking [ITU-T Y.3300]: A set of techniques that enables to directly program, orchestrate, control and manage network resources, which facilitates the design, delivery and operation of network services in a dynamic and scalable manner.

3.1.3 dense WDM (DWDM) device [ITU-T G.671]: A class of WDM devices that have a channel spacing less than or equal to 1000 GHz. Devices within this class can cover one or more spectral bands.

3.1.4 model network [ITU-T Q.3901]: A network which simulates the capabilities similar to those available in telecommunication networks; it has a similar architecture and functionality and uses the same telecommunication technical means.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AR Augmented Reality

DWDM Dense Wavelength Division Multiplexing

ICMP Internet Control Message Protocol

QoS Quality of Service

RTT Round trip time

SDN Software-defined Network

TI Tactile Internet

UDP User Datagram Protocol

5 Conventions

None.

6 Architecture of model network for tactile Internet testing

Before the tactile Internet (TI) services implementation, one of the main tasks is a detailed test of infrastructure acceptability. In providing the tactile Internet services, it must be taken into account that the round-trip delay must not exceed the value of 1 ms (according to the [b-ITU-T TWR TI]). In this regard it is rational to pre-test the infrastructure on the model network that will produce different interaction scenarios of the main components of this system. The model network for tactile Internet applications represents the prototype of the existing network that was built on appropriate hardware. By using this kind of network, it is possible to perform the complex testing of the investigated equipment in both normal operation mode and under the pressure. This allows evaluating of the characteristics with more quality and objectiveness as opposed to testing on the installation object.

The model network structure for the tactile Internet applications testing is presented in Figure 1.

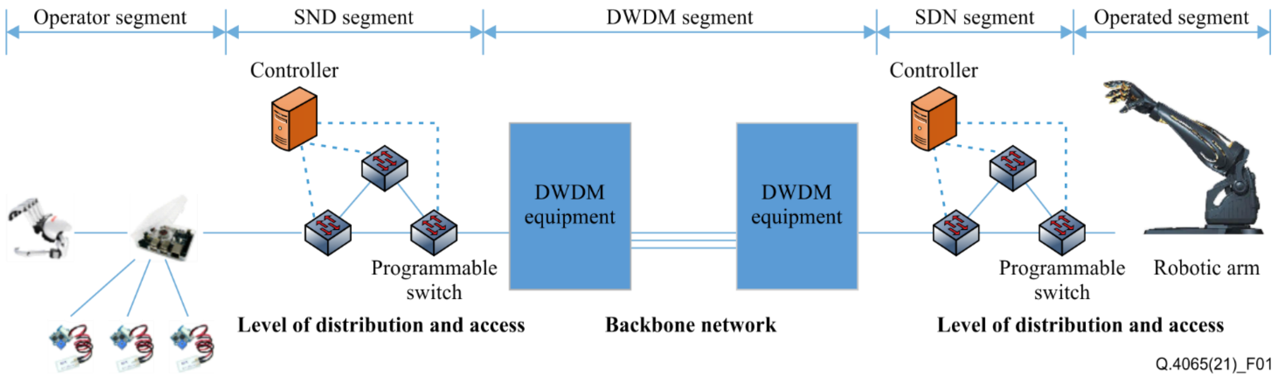

Figure 1 – Model network structure for tactile Internet applications testing

The model network of the tactile Internet consists of the following main components:

Operator segment: Kinesthetic sensors and tactile and kinesthetic actuators may be represented as a variety of sensors that can read the exact movement of the hands and represent feedback to the interface, as shown in Figure 2. It is also possible to use other sensors that can read movements with the aid of sensor devices or augmented reality (AR) applications.

SDN segment: Level of distribution and access is represented as a software-defined network (SDN) fragment with at least two transit nodes that allows data transfer simulation performing through the real network with a capability to change different parameters as delays and packet loss. At this level, classes of network traffic are defined and priorities are set. For traffic generated by tactile Internet applications, priority is set in the light of the need to minimize end-to-end delays.

DWDM segment: Backbone network is represented as dense wavelength division multiplexing (DWDM) fragment network with the data rate more than 10 Gbit/s. With DWDM equipment and an SDN controller connection there is a capability for flexible traffic-QoS-parameters management.

NOTE – According to [b-5G-ENABLED TI], the maximum transmission distance in the DWDM segment must be less than 100 kilometres to meet the requirements of 1 millisecond round-trip time, taking into account that the light propagation in the optic fibre is not the only source of time delay in the network.

Operated segment: Kinesthetic actuators and tactile and kinesthetic sensors are represented as operating mechanisms (e.g., a robotic arm) for performing commands transmitted through the network and collecting tactile information from the environment. The time required for performing commands depends on the technical characteristics of the hardware devices used on the model network.

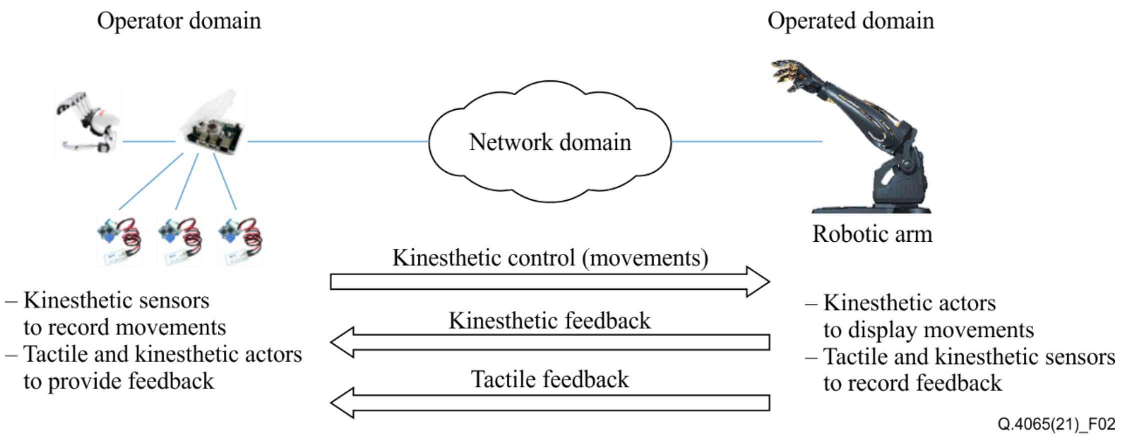

Figure 2 – Data flows in the model network

Additional components of model network include:

– equipment for simulation of public telecommunication networks traffic, including voice and video traffic, IoT traffic;

– a set of measuring equipment (traffic analyser, network performance analyser) connected to the access and distribution network.

7 Network parameters to test

Since tactile Internet applications are critically sensitive to time delay and reliability of the network, it is required to measure the following network parameters while testing.

7.1 Round-trip time (RTT)

This delay comprises all the delays experienced by a communication from origin to destination and back from destination to origin. It includes the time spent in the transmission of the information from the operator domain via the communication infrastructure to the operated domain and back from the operated domain to the operator, including following:

1) Data processing delay in the user equipment both in the operator and operated domains.

2) Queueing, processing, and bufferization delay in the SDN switches, DWDM transmitters, and other network equipment.

3) Propagation delay in all the network segments.

4) Generation of a reaction in the operated domain.

Figure 3 shows round trip time (RTT) estimation.

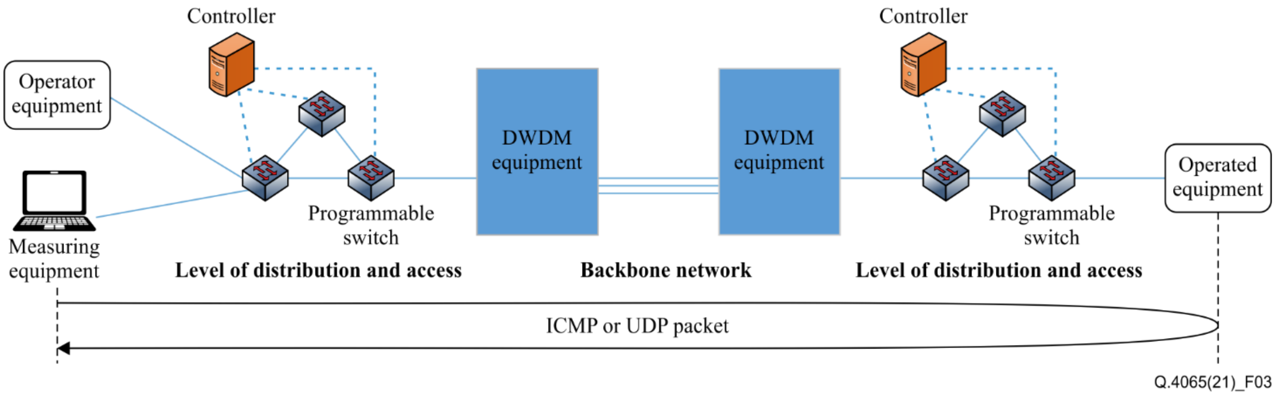

Figure 3 – Round trip time estimation

The importance of this metric lies in the fact that if RTT exceeds the human reaction time (approximately 1 millisecond for the haptic applications), the experience is considered as less realistic, with too great a gap between stimulation and response [b-ITU-T TWR TI].

One of the challenges of RTT estimation for the TI systems is that the delay should be measured in microseconds, as the target RTT for such systems is 1 millisecond. There are two approaches to measure the RTT with the required precision: software tools installed on the computer, and special hardware equipment.

7.1.1 Software tools

The delay may be measured with a variety of similar to "ping" utilities and tools, installed on the model network equipment or computer dedicated to network parameters estimation. These tools send an Internet control message protocol (ICMP) echo request and calculate the time between send and receive with the required degree of accuracy.

Additionally, RTT measurement may be performed using user datagram protocol (UDP) packets sent to the closed port on the operated equipment aimed to receive a "Port unreachable" response. This method allows varying of packet size and other parameters, so the test packets are processed the same way as data packets sent by the terminal equipment.

NOTE – Both methods do not include the data processing delay in the operator and operated equipment, as well as the generation of a reaction in the operated domain. Moreover, delays produced by the host computer software may change the results of the RTT estimation. All these delays should be considered in case of QoS estimation.

7.1.2 Hardware equipment

The network monitoring hardware tools can be used for RTT estimation as well as the other equipment intended to measure network delay. In this case, more reliable results may be obtained, compared to the software approach, as the delays produced by the other computer software is eliminated.

7.2 Delays on each network segment

In case of significant exceedance of required RTT, measurement of delay on each network segment may be useful to understand the sources of additional latency. These delays may be measured as described in clause 7.1, but with alternative target nodes, i.e., the first SDN switch, the DWDM transmitter and receiver. Complementary time on each step represents doubled delay in the access network, SDN, and backbone network respectively, as shown in Figure 4.

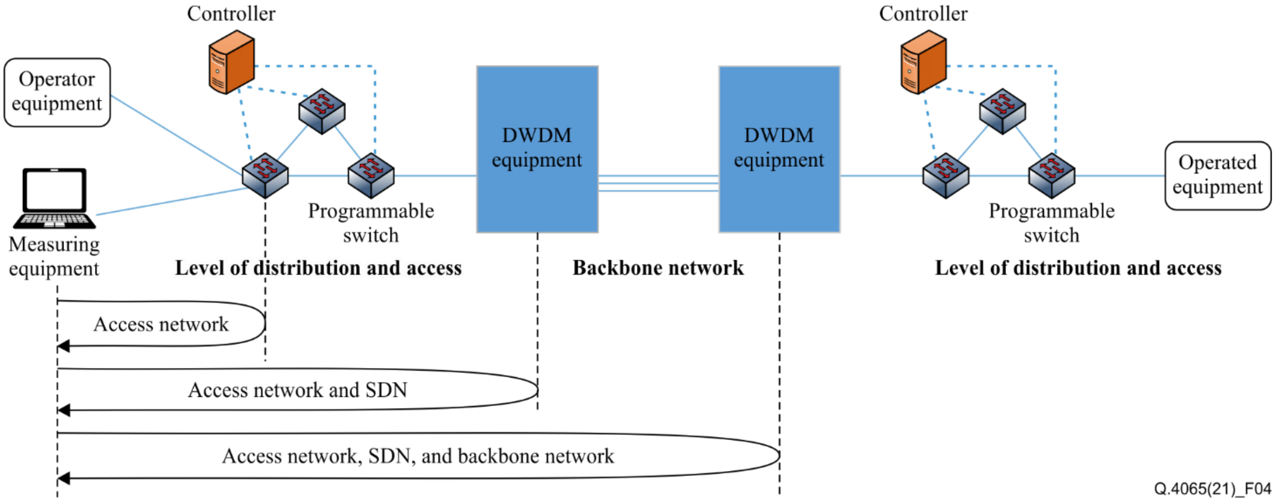

Figure 4 – Measurement of additional delay on each network segment

7.3 Data loss coefficient

The data loss coefficient may be calculated as the percentage of data that have been lost during the end-to-end network transmission. Different applications require different data loss coefficients (in a similar way to IP packet loss coefficient [ITU-T Y.1540]). As well as the time network indicators, the data loss coefficient for the TI systems should be measured with a high precision. It is recommended to use up to 100 000 UDP packets of the same size as actual data packets with the 10-100 millisecond interval sent from the operator segment to the operated segment, and the same amount sent in the opposite direction.

With an equal size of testing packets the data loss coefficient may be calculated as the number of received responses divided by number of sent requests.

8 Model network testing scenarios

To test tactile Internet solutions, it is necessary to specify different testing scenarios for a developed model network. A test procedure may consist of a one or more different test scenarios at the same time. It is possible to define following test scenarios:

1) Tactile and kinesthetic sensors and actuators test. The objective of this scenario is to verify the accuracy of the tactile and kinesthetic sensors' values and tactile and kinesthetic actuators' actions by the special server-side test application.

2) Software defined network switch and controller test. The objective of this scenario is to verify the accuracy of the SDN switch and controller switching, routing, and load balancing functions by special on-controller testing application.

3) Dense wavelength division multiplexing test. The objective of this scenario is to verify the accuracy of the DWDM equipment multiplexing, demultiplexing, packets checking, and other functions by the special server-side test application.

4) Quality of service test. The objective of this scenario is to verify (by the special server-side test application) the values of the different network parameters, e.g., parameters presented in clause 7, are in the required range during data transmission through the model network.

Appendix I

Use cases

(This appendix does not form an integral part of this Recommendation.)

The following use case scenarios may be applied as a part of a testing procedure.

I.1 Movement transmission test

Preconditions: Model network is deployed and ready to test.

Basic flow: Test engineer moves kinesthetic device.

Result: Kinesthetic actuator (physical or virtual) moves in the same way.

I.2 Kinesthetic feedback test

Preconditions: Use case 8.1 Movement transmission test.

Basic flow:

Test engineer moves kinesthetic device.

Kinesthetic actuator interacts with the environment (real or virtual).

Result: Test engineer feels kinesthetic feedback from the remote environment.

I.3 Tactile feedback test

Preconditions: Use case 8.1 Movement transmission test.

Basic flow:

Test engineer moves kinesthetic device.

Kinesthetic actuator interacts with the environment (real or virtual).

Tactile sensors receive tactile information from the environment.

Result: Test engineer feels tactile feedback from the remote environment with a tactile actuator.

The last use case should be repeated for every tactile feedback channel (e.g., vibration, temperature, macroscopic roughness).

More detailed use cases should be created for specific applications according to their characteristics.

Bibliography

[b-ITU-T TWR TI] ITU-T Technology Watch Report (2014), *The Tactile Internet*.

[b-5G-ENABLED TI] M. Simsek, A. Aijaz, M. Dohler, J. Sachs and G. Fettweis (March 2016), *5G-Enabled Tactile Internet*, in *IEEE Journal on Selected Areas in Communications*, vol. 34, no. 3, pp. 460-473, doi: 10.1109/JSAC.2016.2525398.

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