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Internet of things and smart cities and communities – Frameworks, architectures and protocols

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Architectural framework for transportation safety services

Recommendation ITU-T Y.4457

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GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	
General	Y.4000–Y.4049
Definitions and terminologies	Y.4050–Y.4099
Requirements and use cases	Y.4100–Y.4249
Infrastructure, connectivity and networks	Y.4250–Y.4399
Frameworks, architectures and protocols	**Y.4400–Y.4549**
Services, applications, computation and data processing	Y.4550–Y.4699
Management, control and performance	Y.4700–Y.4799
Identification and security	Y.4800–Y.4899
Evaluation and assessment	Y.4900–Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.4457

Architectural framework for transportation safety services

Summary

Accidents and disasters caused by various means of transportation affect many lives and properties. Transportation safety can be influenced by defective vehicles (e.g., cars, trains, ships), environmental status (e.g., wind, snow, low temperatures), disruption to transportation infrastructures (e.g., bridges, tunnels, roads) and human error. Transportation safety services based on Internet of things (IoT) technologies can reduce the occurrence of accidents and disasters, save lives and reduce damage to properties.

Recommendation ITU-T Y.4457 describes a transportation safety management model and an architectural framework for transportation safety services based on the IoT reference model.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Architecture, framework, IoT, transportation safety management model, transportation safety service.

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Table of Contents

		Page
1	Scope	1
2	References	1
3	Definitions	2
	3.1 Terms defined elsewhere	2
	3.2 Terms defined in this Recommendation	3
4	Abbreviations and acronym	3
5	Conventions	3
6	Overview of transportation safety services	3
7	Transportation safety management model and safety measurement parameters	4
	7.1 Transportation safety management model	4
	7.2 Safety measurement parameters	6
8	Architectural model for transportation safety services	6
	8.1 Device layer	7
	8.2 Network layer	9
	8.3 Service support and application support layer	10
	8.4 Application layer	12
Annex A – The creation of a safety index and safety knowledge		14
Annex B – The creation of driver tiredness knowledge		16
Appendix I – Sensing data pre-processing procedure		18
	I.1 Sensing data pre-processing in a vehicle	18
	I.2 Sensing data pre-processing in adjacent vehicle	19
Appendix II – Characteristics of transportation application services		22
Bibliography		25

Recommendation ITU-T Y.4457

Architectural framework for transportation safety services

1 Scope

This Recommendation addresses a transportation safety management model that describes disaster management steps based on Internet of things (IoT) technologies in order to reduce damage from disasters. An architectural model for transportation safety services is described based on [ITU-T Y.4116] and on requirements according to the IoT reference model [ITU-T Y.4000].

The scope and characteristics of transportation disasters from various transportations (e.g., road, railway, maritime and air transportation) are based on [ITU-T Y.4116]. Transportation safety management parameters (e.g., safety index and driver tiredness) are presented respectively in Annex A and Annex B and sensing data pre-processing procedure and characteristics of transportation application services are described in the appendices of this Recommendation.

NOTE – In this Recommendation, some capabilities (e.g., driver condition monitoring, infrastructure monitoring) and some applications (e.g., road/train/maritime/air safety management services) may be related to regulation in some countries. In this case, non-functional aspects related to regulation are out of scope and functional aspects cannot supersede existing regulation. Regulatory issues may be subject to laws (e.g., intelligent transportation system (ITS) related regulation).

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 E.108] Recommendation ITU-T E.108 (2016), *Requirements for a disaster relief mobile message service.*

[ITU-T F.749.1] Recommendation ITU-T F.749.1 (2015), *Functional requirements for vehicle gateways.*

[ITU-T Y.4000] Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things.*

[ITU-T Y.4050] Recommendation ITU-T Y.4050/Y.2069 (2012), *Terms and definitions for the Internet of things.*

[ITU-T Y.4101] Recommendation ITU-T Y.4101/Y.2067 (2017), *Common requirements and capabilities of a gateway for Internet of things applications.*

[ITU-T Y.4116] Recommendation ITU-T Y.4116 (2017), *Requirements of transportation safety services including use cases and service scenarios*.

[ITU-T Y.4401] Recommendation ITU-T Y.4401/Y.2068 (2015), *Functional framework and capabilities of the Internet of things.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 disaster [b-ITU-T FG-DR&NRR]: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

3.1.2 Internet of things (IoT) [ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.3 logistics satisfaction index [ITU-T Y.4116]: An index that reflects the degree of satisfaction of an owner of goods during a delivery process.

NOTE – For example, the logistics satisfaction index may be evaluated by considering the delivery experience of goods on the delivery route and the facilities of the delivery vehicles.

3.1.4 safety index (safety level) [ITU-T Y.4116]: A numerical value indicating the health status of transportation infrastructure or vehicle at a given time. A low safety index means a critical health status of the transportation infrastructure or vehicle.

NOTE – As an example of specific transportation infrastructure safety index, the type of road such as mountain road and urban road, and the road health status such as irregularity and flatness, pothole, accident status, etc., are evaluated for the road safety index. The road safety index can be adjusted in its evaluation other parameters such as the type of vehicle and the driver characteristics such as gender, age.

3.1.5 thing [ITU-T Y.4000]: In the Internet of things, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks.

3.1.6 vehicle [ITU-T Y.4116]: A means of transportation in air, maritime or surface environments.

NOTE – Examples of vehicles include cars, ships, flights, trains, unmanned aerial systems (UASs).

3.1.7 vehicle gateway (VG) [ITU-T F.749.1]: A VG is a device in a vehicle that enables communications between a device in the vehicle and another device which may be physically located either inside the vehicle or outside the vehicle (e.g., roadside station, cloud-based server, etc.). A VG provides standardized interfaces and protocols, communications across heterogeneous networks, optimized network selection based on application needs and network quality of service (QoS), arbitration and integration of network communications, security and switching network connections to maintain service continuity.

3.1.8 virtual sensor (soft sensor) [ITU-T Y.4116]: A kind of sensor that uses information available from various measurements including process measurement parameters, to estimate the quantity of interest. A virtual sensor can process measurement parameters from physical sensors or other virtual sensors.

NOTE 1 – Some virtual sensors may convert parameters of physical domains to logical domain values, e.g., for specific monitoring purposes. Also, some virtual sensors may realize this conversion among multiple domains, e.g., a "freezing" sensor can be finally assembled from temperature sensor(s) and humidity sensor(s).

NOTE 2 – As an example, in case of transportation safety, the vibration of a vehicle and the elevation, humidity, temperature and freezing status of the road, may be considered to create a virtual sensor for transportation safety.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronym

This Recommendation uses the following abbreviations and acronyms:

AP	Access Point
API	Application Programming Interface
CCTV	Closed Circuit Television
DTN	Delay Tolerant Network
GPS	Global Positioning System
GUI	Graphical User Interface
ICT	Information and Communication Technology
IoT	Internet of Things
IP	Internet Protocol
ITS	Intelligent Transportation System
LPI	Logistics Performance Index
PPDR	Public Protection and Disaster Relief
QoS	Quality of Service
RDF	Resource Description Framework
RSE	Road Side Equipment
UAS	Unmanned Aerial System
VG	Vehicle Gateway
V2V	Vehicle to Vehicle
WCN	Wideband Communication Network
WSN	Wireless Sensor Network

5 Conventions

None.

6 Overview of transportation safety services

Transportation accidents and disasters have an effect on lives and properties and there are many factors such as abnormal status of vehicles (e.g., cars, trains, ships) and transportation infrastructures (e.g., bridges, tunnels, roads), and driver's driving status (e.g., tiredness, drunk, sleeping) that can influence accidents and injuries. It is essential to prevent disasters and reduce the damage from disasters by continuously monitoring the status of vehicles, transportation infrastructures and driver's driving status. Therefore, this Recommendation addresses the use of Internet of things (IoT) technologies to prevent transportation accidents and disasters.

There are some intelligent transportation system (ITS) related standards such as [b-ISO 15638-7], [b-ISO 15638-12], [b-ISO 15638-17] and [b-ISO 13185-2] that define the framework for telematics and vehicle interfaces for provisioning and support of ITS services to resolve traffic problems by providing traffic information collection service, telematics service, etc., but these standards do not include transportation disaster management related technologies. To resolve transportation accidents and disasters [ITU-T Y.4116] describes requirements for providing transportation safety services including the use cases and related service scenarios. Based on [ITU-T Y.4116], the present Recommendation provides a transportation safety management model and an architectural framework for transportation safety services based on the IoT reference models presented in [ITU-T Y.4000]. These models are applicable to various transportation services (e.g., vehicles, railway, maritime, air transportation).

7 Transportation safety management model and safety measurement parameters

This clause presents a transportation safety management model and safety measurement parameters (safety knowledge and driver tiredness knowledge), which can be used to analyse the safety status of vehicles and transportation infrastructures as well as drivers' driving status.

7.1 Transportation safety management model

This clause presents a transportation safety management model to prevent disasters and reduce the damage from disasters. The transportation safety management model, shown in Figure 1, consists of 5 steps as follows:

– Monitoring early warning of disaster;
– Disaster detection;
– Disaster simulation;
– Disaster countermeasure;
– Disaster prevention.

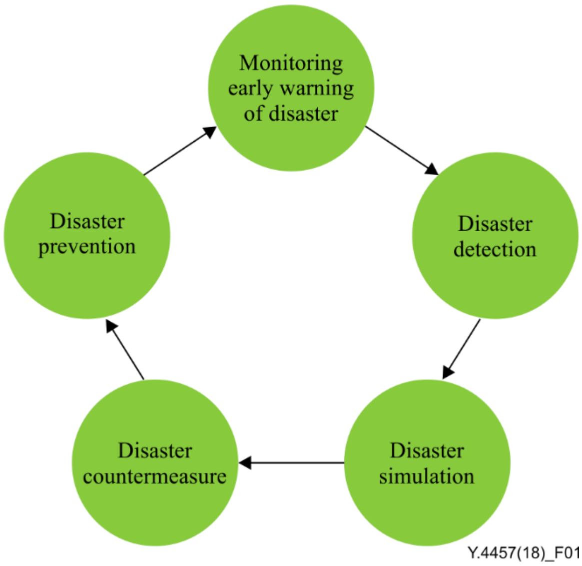

Figure 1 –Transportation safety management model

7.1.1 Monitoring early warning of disaster

In order to prevent or mitigate damages from the disaster, it is necessary to monitor early warnings of disaster accurately. The measuring parameters that can be used to anticipate disasters are temperature, vibration, humidity, weather, etc. Disaster monitoring can be done in a distributed manner by clients in vehicles and servers in consideration of vehicle mobility. The threshold values for the anticipation of disasters in vehicles can be delivered from a network server [ITU-T Y.4116]. During the monitoring procedure, the following data are used:

– IoT sensing data from vehicles (e.g., temperature, vibration, velocity of vehicle, etc.);
– IoT sensing data from transportation infrastructures (e.g., temperature, vibration, etc.);
– IoT sensing data from surrounding environment (e.g., temperature, fire, fog, etc.);
– Virtual IoT sensing data created by converging various IoT sensing data.

7.1.2 Disaster detection

In order to detect disasters in real time, it is necessary to analyse the various kinds of IoT sensing data quickly and increase the detection probability of disasters by combining several IoT data. Since IoT sensing data are changed in a certain range according to time, the measured sensing data are filtered in a certain period to increase the detection probability of disasters. The threshold value of each IoT sensing data is defined by cooperating vehicles and network servers and several IoT sensing data with multimedia formats to detect disasters with high accuracy. Abnormal operation of IoT sensors must be recognized to avoid false alarms.

7.1.3 Disaster simulation

The disaster simulation is used in order to estimate the magnitude, type and propagation time of a disaster. It is necessary to simulate the disaster in three dimensions to analyse the damage for accurate countermeasures and to prevent secondary damage. The affected disaster area depends on the magnitude and type of the disaster and environmental factors (e.g., temperature, fog, etc.).

7.1.4 Disaster countermeasure

It is necessary to counteract rapidly after disaster detection and simulation to save lives and to reduce the damage. The disaster countermeasure procedure can be approached differently according to the disaster magnitude. A systematic countermeasure from the disaster is managed by a disaster control centre as follows:

– An emergency communication network including wired and/or wireless communication facilities should be provided within a limited time.

NOTE – Unmanned aerial systems (UASs) can provide wireless communication links to support an emergency countermeasure and to support wireless sensing networks to monitor the status of disasters, for example using airdrop sensors and delay tolerant network (DTN) equipment [b-IETF RFC 4838] and [b-IETF RFC 5050].

– An alert signal can be issued differently according to the nature of the disaster. In case of road accidents, a message indicating a detour may be transmitted to the related area.
– A disaster relief procedure should be provided in order to reduce the damage by connecting related organizations (e.g., fire station, hospital, etc.) [ITU-T E.108].

7.1.5 Disaster prevention

Since an efficient maintenance procedure for vehicles and transportation infrastructures can prevent a disaster, it is necessary to monitor vehicles and transportation infrastructures periodically or intermittently according to the safety level as follows:

– Create a safety index [ITU-T Y.4116] of vehicles and transportation infrastructures based on IoT sensing data:
  • periodic sensing is necessary to perform health monitoring of vehicles and transportation infrastructures to ensure that the safety index is in normal status;
  • short periodic sensing or non-periodic sensing scheduling is necessary to ensure that the safety index is in different status.
– In order to increase the disaster prevention ratio, the repair history data can be considered.

NOTE – In case of a public transportation company, when vehicles enter a designated repair centre, repair information may be gathered automatically and be sent to a management centre to create a database for maintenance history.

– When the anticipatory sign of a disaster is detected, an urgent disaster prevention procedure should be initiated by sending an alert signal to related organizations and/or entities (e.g., road corporation, road transportation company, railway company, driver, etc.).

7.2 Safety measurement parameters

7.2.1 Safety knowledge

It is necessary to use safety related parameters to evaluate vehicles and infrastructure quantitatively. One of the measuring parameters used to evaluate safety is a safety index. A safety index represents a numerical value indicating the current health status of an object [ITU-T Y.4116] and safety knowledge represents the health state of an object using a safety index at a given condition (e.g., weather and time, etc.). The safety knowledge can be different for the same object according to the conditions (e.g., an environment and time, season, etc.). When the safety knowledge is created, the repair history of a vehicle and/or an infrastructure is used to estimate more accurately the safety status [ITU-T Y.4116].

NOTE 1 – Details of safety index and safety knowledge are shown in Annex A.

NOTE 2 – Transportation service companies can use safety knowledge to maintain vehicles in order to prevent disasters. Road corporations and railway companies can use safety knowledge to maintain transportation infrastructures.

7.2.2 Driver tiredness knowledge

Since driver tiredness affects transportation disasters, it is necessary to manage driver tiredness using IoT bio-sensing data that can be acquired during driving using a non-constraining or non-stimulative method.

Driver tiredness knowledge is managed by a tiredness index that indicates the degree of tiredness of a driver. A tiredness index differs for each person in the same bio signal conditions, according to individual characteristics (e.g., gender, age, illness, etc.).

NOTE 1 – Transportation service companies can use driver tiredness knowledge to administrate drivers to prevent disasters. For measuring tiredness, there are two kinds of methodology:

– the tiredness measurement using IoT sensors in a car;
– the cooperative measurement: a driver can cooperate with an administration centre using an actuator attached on the steering wheel and road side equipment (RSE) installed on road in the case of road transportation.

NOTE 2 – Details of driver tiredness knowledge are shown in Annex B.

8 Architectural model for transportation safety services

Figure 2 shows an architectural model for transportation safety services based on the IoT reference model in [ITU-T Y.4000]. It is composed of four layers as follows:

– Device layer;
– Network layer;
– Service support and application support layer;
– Application layer.

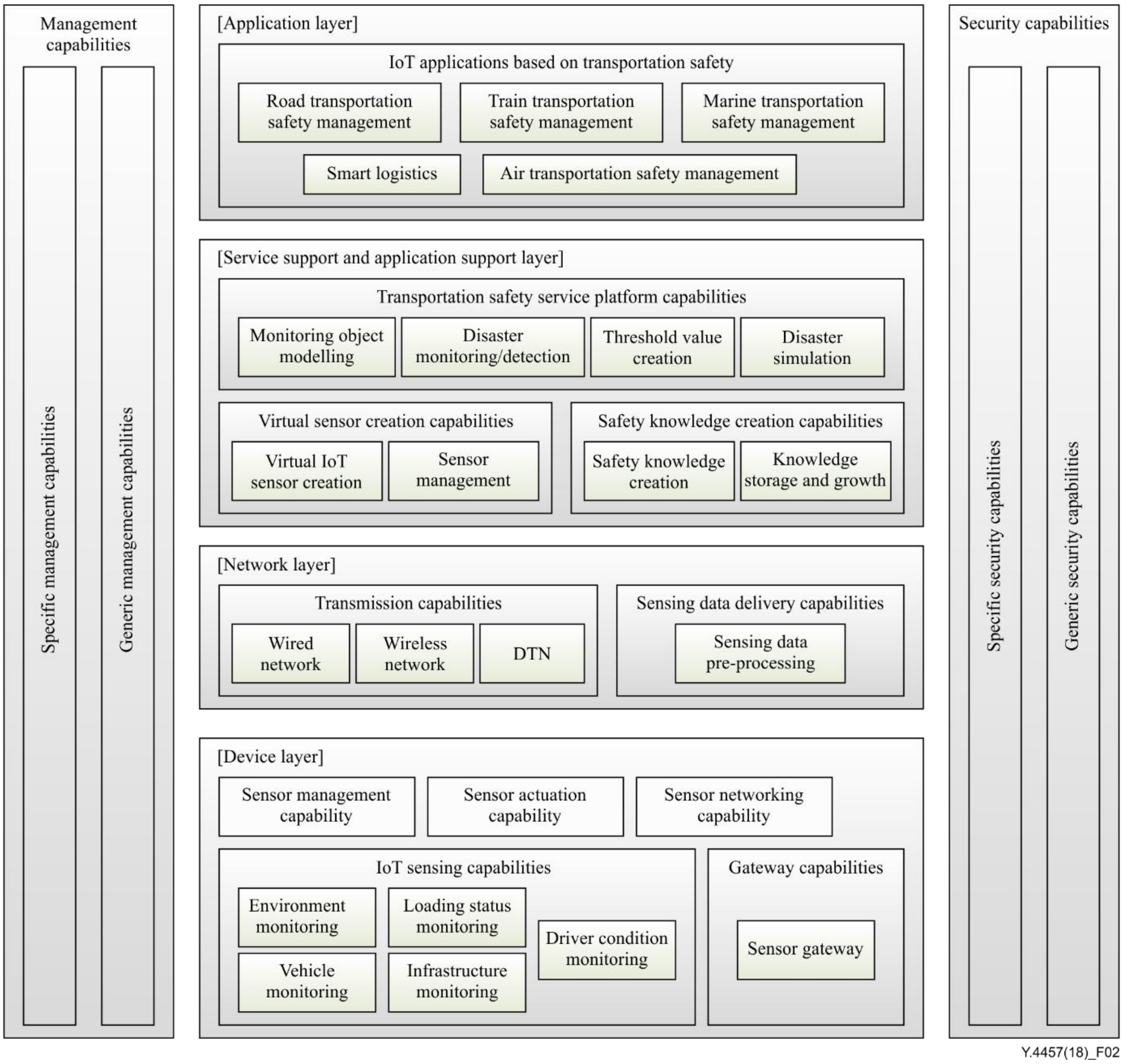

Figure 2 – Architectural model for transportation safety services

8.1 Device layer

The device layer supports various capabilities to acquire sensing data and deliver it to a network layer.

8.1.1 Sensor management capability

This capability supports sensor establishment and generates the control message for detecting the status of sensor operation and for managing sensors. The status information of a sensor is reported to a service support and application support layer via a sensor gateway to support sensor management capability as follows:

– When any IoT sensor does not work, other sensors can be operated substituting it.

NOTE – Details of substituting sensing data are shown in Appendix I.

– When IoT sensing data has an abnormal status, sensor management capability can calibrate the abnormal IoT sensor in collaboration with the sensor actuation capability.

– Sensor management capability manages the power status of a sensor to extend the operating life and to control the transmission period of measured data.

8.1.2 Sensor actuation capability

This capability generates a sensor control message to operate a sensor for the purpose of demand as follows:

– IoT sensor calibration for the purpose of refreshing;

– Virtual IoT sensor creation by controlling the IoT sensor operation.

8.1.3 Sensor networking capability

This capability supports the configuration of a wireless sensor network (WSN) for vehicles and transportation infrastructures.

– In the case of vehicles, WSN can be configured in internal and external environments from the vehicles (e.g., sensor nodes in a vehicle can be connected to access points (AP) installed in infrastructures).

– In the case of trains, in order to extend the service coverage of WSN, multi-hop relay and mesh networking can be used in trains.

8.1.4 Sensor gateway capability

This capability supports the interconnection between WSN and a wideband communication network (WCN) (e.g., backbone network or mobile communication network) for IoT operation [ITU-T Y.4101]. All of the sensing data are delivered to a network layer via a sensor gateway. A sensor gateway performs the protocol conversion function between WSN and WCN. In addition, a sensor gateway provides the graphical user interface (GUI) based monitoring function to display safety information on the terminal screen (e.g., a vehicle gateway (VG) in a vehicle [ITU-T F.749.1] or a sensor gateway in a train locomotive can gather sensing data and display safety information).

8.1.5 IoT sensing capabilities

8.1.5.1 Vehicle monitoring

This capability supports the vehicle monitoring that measures various parameters (e.g., temperature, vibration, balance, tire pressure in the case of a road vehicle, etc.). An analogue value of sensing data is converted to a digital value for an estimation process and transmission to a transportation safety service platform. The sampling rate of a sensor can be changeable according to the power status of the sensor and interference level of a WSN. The sensing data are compared with the predefined threshold value to detect the abnormal status of an object in real time. In the case where measured sensing data is abnormal, alert information has to be generated in real time.

In addition the repair history of a vehicle can be registered in a database to estimate the possibility of failure.

8.1.5.2 Infrastructure monitoring

This capability supports the monitoring for transportation infrastructures. The various parameters (e.g., vibration, cracks and pot-holes in the case of road transportation) are measured to estimate the safety index to prevent an accident caused by the abnormal status of an infrastructure. Sensors installed in a vehicle or sensors installed in a transportation infrastructure measure various parameters from an infrastructure in real time and deliver these parameters to service support and application support layers.

8.1.5.3 Environment monitoring

This capability supports the monitoring of the surrounding environment of vehicles and transportation infrastructures. The various parameters (e.g., freezing, fog, road slipperiness, etc.) are measured to estimate indications of a possible accident. Sensors installed in a vehicle or sensors installed in a transportation infrastructure measure environmental parameters in real time and deliver these parameters to service support and application support layers.

8.1.5.4 Loading status monitoring

This capability supports the loading status monitoring that measures the loading status of vehicles, and weight status of vehicles to estimate the effect of an accident, because the overloading of a vehicle can cause an accident (e.g., overturning, derailment).

8.1.5.5 Driver condition monitoring

Since transportation accidents can be induced not only by an abnormal status of transportation infrastructures, but also by driver tiredness, it is necessary to monitor the status of the driver.

This capability supports driver condition monitoring to prevent an accident caused by a driver's tiredness. A bio-signal can be monitored by unconstrained signal measurements or unconsciousness measurements during driving status. Driver tiredness can be measured by a bio-signal or a driver's response delay time.

NOTE – In order to assure safe driving, a driver and roadside equipment can cooperate with each other for measuring a driver's tiredness and for refreshing the tired driver (e.g., roadside equipment sends the test sequence message to measure the response time of a driver.). If the response time is beyond the predefined duration, the roadside equipment estimates the tiredness of a driver and performs counteractive activities.

8.2 Network layer

8.2.1 Networking capabilities

For networking capabilities, an Internet protocol (IP) packetizing algorithm considering the encapsulation of multiple sensing data supports delivery of the sensing data to a transportation safety service platform.

8.2.1.1 Wired network

This capability supports the interconnection for delivering sensing data to a service support and application support layer using a wired network (e.g., optical or Ethernet network). A wired network is useful for infrastructure monitoring and wideband multimedia data transmission for example a closed circuit television (CCTV).

8.2.1.2 Wireless network

This capability supports the interconnection for delivering sensing data to a service support and application support layer using a wireless/mobile network. IoT sensing data can be delivered to the service support and application support layer via a Wi-Fi network in place of a mobile network.

There are two methodologies (i.e., periodic transmission and event driven transmission) to deliver sensing data to a transportation safety service platform.

8.2.1.3 Delay tolerant network

This capability supports interconnection between a WSN and Internet network where there are no permanent backbone networks. IoT sensing data can be compressed considering the characteristics of sensing data to be stored in a delay tolerant network (DTN) gateway during the disconnection period of backbone links. Thereafter reconnecting the backbone link, DTN functionality transmits the stored sensing data with timing information.

NOTE – UAS or a smart phone can provide intermittent backbone links to deliver stored sensing data in a DTN gateway.

8.2.2 Sensing data pre-processing capabilities

8.2.2.1 Sensing data pre-processing

When considering a wireless network that is limited to the transmission data rate, it is necessary to reduce transmission data volumes. Sensing data pre-processing capability is required according to the characteristics of sensing data (e.g., occurrence, value range, duplication, etc.).

The duplication of sensing data includes duplication among current sensing data, duplication between current and pre-transmitted sensing data and duplication among platooning vehicles. The compression technique for duplication data includes average calculation or data substitution among adjacent vehicles.

Invalid sensing data whose values are beyond a predetermined range cannot be delivered to a transportation safety service platform. In this case, this capability supports a reset or calibration of the abnormal sensors.

NOTE – Appendix I presents details of sensing data pre-processing procedure.

8.3 Service support and application support layer

8.3.1 Virtual sensor creation capabilities

8.3.1.1 Virtual IoT sensor creation

This capability supports the IoT sensor creation that creates a new IoT sensor combining several IoT sensors for the purpose of monitoring certain objects [ITU-T Y.4116]. This capability can easily measure various parameters without the establishment of new physical IoT sensors. If it is necessary to control sensors from a remote location for the creation of a virtual IoT sensor, this functionality can cooperate with the sensor management capability.

NOTE – When a virtual IoT sensor is created, some sensors may be controlled to adjust the sensing range or sampling frequency, or substitute other sensors, etc.

8.3.1.2 Sensor management

This capability supports the sensor management that monitors IoT sensor status (e.g., normal and abnormal status and power levels, etc.). Also IoT sensors installed in vehicles or transportation infrastructures can be calibrated from a remote site by this capability. This capability cooperates with the sensor management capability in the device layer.

8.3.2 Transportation safety service platform capabilities

There are several capabilities in a transportation safety service platform as shown in Figure 2. These capabilities are related to each other as shown in Figure 3.

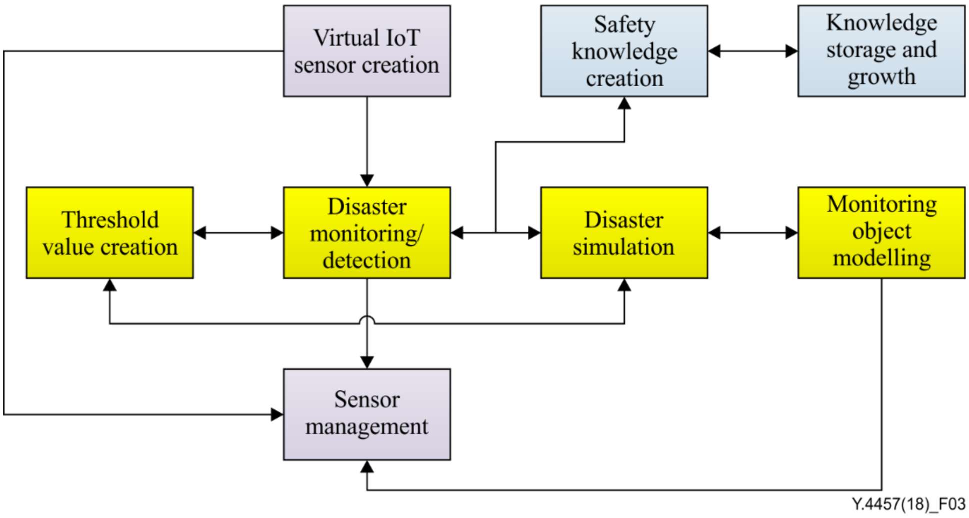

Figure 3 – The relationship among capabilities in a transportation safety service platform

8.3.2.1 Monitoring object modelling

This capability classifies vehicles and transportation infrastructures into several models in order to support IoT sensor establishment and simulation.

NOTE 1 – When a new IoT sensor has to be established, an IoT sensor establishment point and the number of IoT sensors can be determined by this functionality. In this case, the IoT sensor establishment point can be determined according to the correlation value of sensing data among sensors. Also it is possible to predict disasters by the disaster simulation capability using an object model.

NOTE 2 – As an example, it is possible to decide the IoT sensor establishment location in a bridge using a bridge model and to create a bridge disaster prediction model based on a bridge model.

8.3.2.2 Disaster simulation

This capability supports the prediction of disasters by generating a disaster prediction model in cooperation with the monitoring object modelling capability using IoT sensing data. This capability performs the following specific tasks:

– Supports the creation of threshold values for the detection of disaster in cooperation with threshold value creation capability.

– Evaluates the effects of disaster after occurrence of disaster, e.g., estimating the size and seriousness of disaster using IoT sensing data to counteract accident.

8.3.2.3 Disaster monitoring and detection

This capability supports disaster monitoring and detection that monitors the signs of disasters in real time. When the measured data have reached threshold values, it is estimated as disaster occurrence; thereafter this information is delivered to the disaster simulation capability. The level of disaster is classified according to the predefined threshold values.

This capability operates in a distributed manner between the device layer in vehicles and the service support and application layer in a disaster management centre to ensure the fast and accurate detection of disasters and countermeasures.

8.3.2.4 Threshold value creation

This capability creates threshold values of various sensing data by cooperating with the disaster simulation capability for monitoring and detecting disasters. Multilevel threshold values are determined to indicate various safety levels and these values are adjusted according to the observation goal (e.g., disaster type and object entity). Threshold values are delivered to the entity for the disaster monitoring and detection capability that can be implemented in a vehicle and a disaster management centre.

8.3.3 Safety knowledge creation capabilities

8.3.3.1 Safety knowledge creation

This capability creates the safety knowledge that estimates the degree of safety of transportation vehicles and transportation infrastructures at a given condition by analysing IoT sensing data.

– In case of transportation infrastructures, safety knowledge is generated by analysing the IoT sensing data of infrastructures and surrounding environmental parameters (e.g., vibration and temperature, humidity, etc.);

– In case of vehicles, safety knowledge is generated by analysing IoT sensing data and the history of repair.

NOTE – Annex A presents details of safety knowledge creation.

8.3.3.2 Knowledge storage and update

This capability stores the generated safety indices with context information in an appropriate format (e.g., a RDF triple form) as shown in Annex A and updates the knowledge according to the renewed IoT sensing data continuously. The safety knowledge of objects can be different from each other in the same conditions (e.g., the safety index of a small car is different from the safety index of a heavy car in the same place.). Also the safety knowledge can be changed according to the other parameters (e.g., weather and seasons, etc.).

8.4 Application layer

This layer provides application services using IoT sensing data for transportation safety. The application provider utilizes various IoT sensing data and capabilities as shown in Figure 2 in order to provide IoT application services to application customers [ITU-T Y.4000].

8.4.1 IoT applications based on transportation safety

There are several IoT applications based on transportation safety related to IoT sensing data and capabilities. This clause introduces transportation safety management services for road, railway, maritime and air transportation (e.g., UAS) including smart logistics. All of service procedures have to be worked in real time within a limited time.

8.4.1.1 Road transportation safety management service

This service supports open application programming interfaces (APIs) to create the monitoring and detecting, counteracting functions to reduce the loss of lives and damage caused by transportation disasters in a road transportation environment.

NOTE – The characteristics of a transportation safety management service are shown in Table II.1 in Appendix II.

8.4.1.2 Railway transportation safety management service

This service supports open APIs to create the monitoring and detecting, counteracting functions from disasters in a railway environment.

NOTE – The characteristics of a railway transportation safety management service are shown in Table II.2 in Appendix II.

8.4.1.3 Marine transportation safety management service

This service supports open APIs to create the monitoring and detecting, counteracting functions from disasters in a marine transportation environment.

NOTE – The characteristics of a marine transportation safety management service are shown in Table II.3 in Appendix II.

8.4.1.4 Air transportation safety management service

This service supports open APIs to create monitoring and detecting functions to reduce disasters caused by air transportation (e.g., UAS).

NOTE – The characteristics of UAS safety management service are shown in Table II.4 in Appendix II.

8.4.1.5 Smart logistics service

This service supports open APIs to create monitoring and evaluation functions in goods delivery.

The scope of an evaluation function is as follows:

– Logistics satisfaction index: This means an indicator obtained by the weighted satisfaction scores that can be calculated on the basis of a certain standard from the experienced environmental parameters (e.g., vibration, temperature, etc.) during delivery.

– Vehicles trust index: This means an indicator obtained by the weighted trust scores that can be calculated on the basis of a certain standard from the experienced environmental parameters (e.g., vibration, temperature, accidents, etc.) during delivery.

– The trust index of a delivery company: This is evaluated by logistics performance index (LPI) [b-LPI] and logistics satisfaction index.

NOTE – The characteristics of smart logistics service is shown in Table II.5 in Appendix II.

Annex A

The creation of a safety index and safety knowledge

(This annex forms an integral part of this Recommendation.)

The annex describes safety index calculation and safety knowledge creation.

A safety index can be calculated by several methods. One of the methods for calculating a safety index is as follows [ITU-T Y.4116]:

$$\mathrm{SI} = \sum_{j=1}^{m} W_j \cdot \frac{\sum_{i=1}^{k}\{SS_{i\_}\max - D_i\} \cdot T_i}{D_T}$$

SI: safety index

W_j: weight factor for IoT sensor j

SS_i_max: the maximum value of safety score, which means the best safety status. Safety score is allocated according to the status of an object, that is, the maximum value is assigned when an object is at the highest safe status, meanwhile, the minimum value is assigned when an object is at the lowest safe status as shown in Figure A.1

D_i: offset value from *SSi*_max. This offset value can be determined based on the historical data

T_i: observation time slot duration for the renewal of a safety index

D_T: total time duration for the generation of a safety index

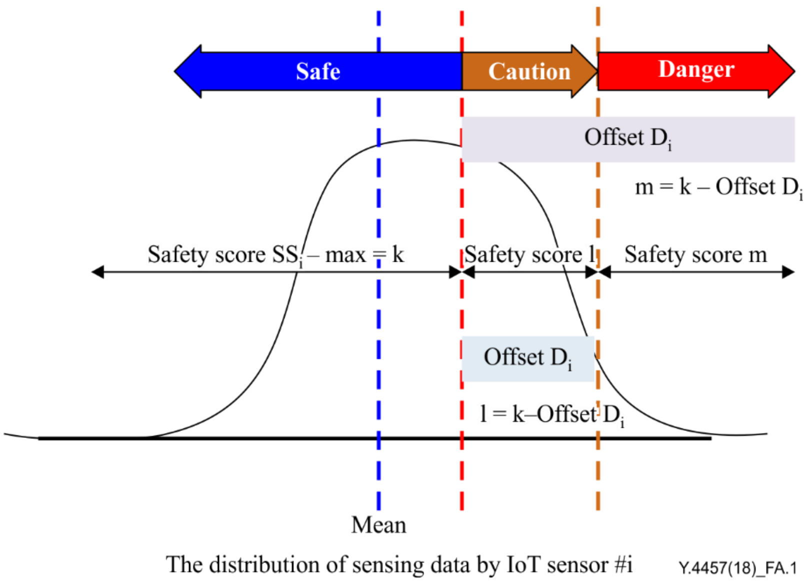

Figure A.1 – The concept of safety score allocation

In order to create the safety knowledge, firstly safety scores of objects and surrounding environment should be generated as shown in Figure A.2. Thereafter a safety index for an object is generated combining several sensing data in the consideration of weight parameters. Safety knowledge can be created according to condition parameters of an object.

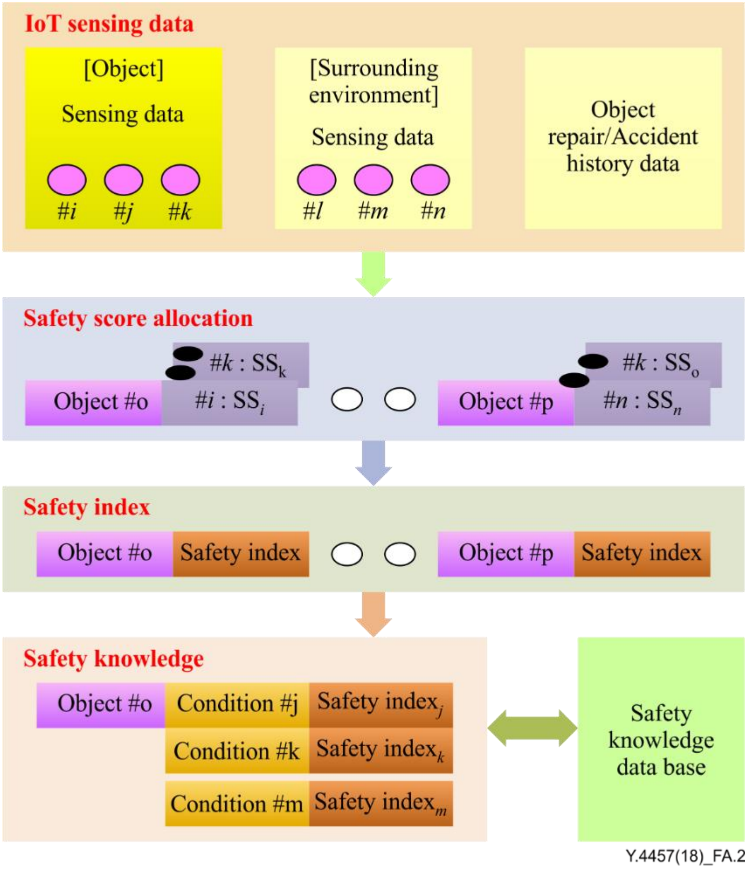

Figure A.2 – The concept of safety knowledge creation

Annex B

The creation of driver tiredness knowledge

(This annex forms an integral part of this Recommendation.)

There may be several kinds of methods used for measuring the driver tiredness (e.g., the bio-signal measurement of driver in a car, monitoring the driver's posture, etc.). In this annex, a cooperative method between a driver and an administration centre is described in Figure B.1. In this case, an administration centre sends test sequence messages to a vehicle through a road side equipment (RSE) and then, a driver responds to test sequence messages using an actuator attached on the steering wheel while driving (e.g., test sequence messages may consists of "push left button, push right button, push right button, etc."). An administration centre can estimate the tiredness of a driver by analysing the response time from a driver as shown in Figure B.2 (a).

When the vehicle is in a predefined emergency state, the vehicle suspends to send test sequence messages to a driver and the vehicle transmits automatically an automatic emergency state notification message to the administration centre. If RSE and the administration centre receive an automatic emergency state notification message, they stop counteractive activities related to the driver tiredness.

In Figure B.2 (b), if the driver's response message arrives in RSE within a permissible time limit, it is estimated that the driver is in normal state. If the response message arrives in RSE beyond the permissible time limit, the driver's tiredness is evaluated such as caution status, tired status, etc., according to the delayed time values. In case of tiredness status, the RSE send the counteract message to the vehicle for preventing disasters.

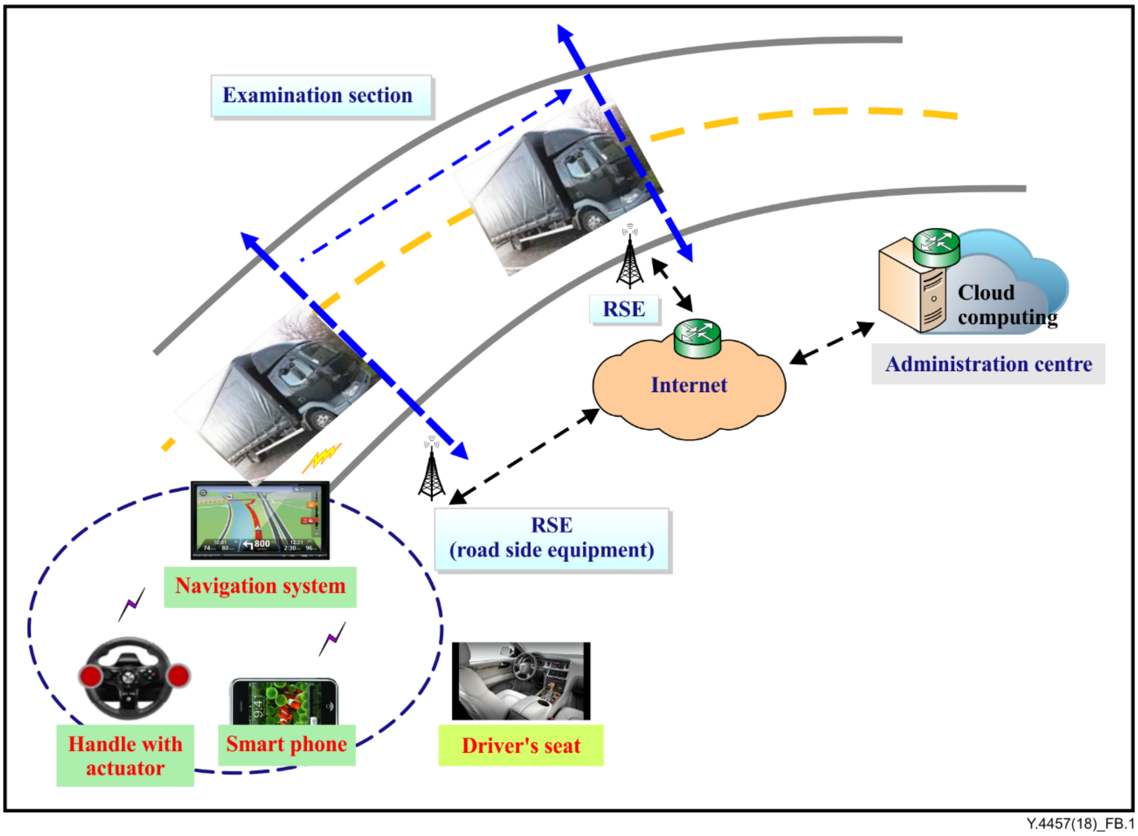

Figure B.1 –The concept of driver's tiredness measurement

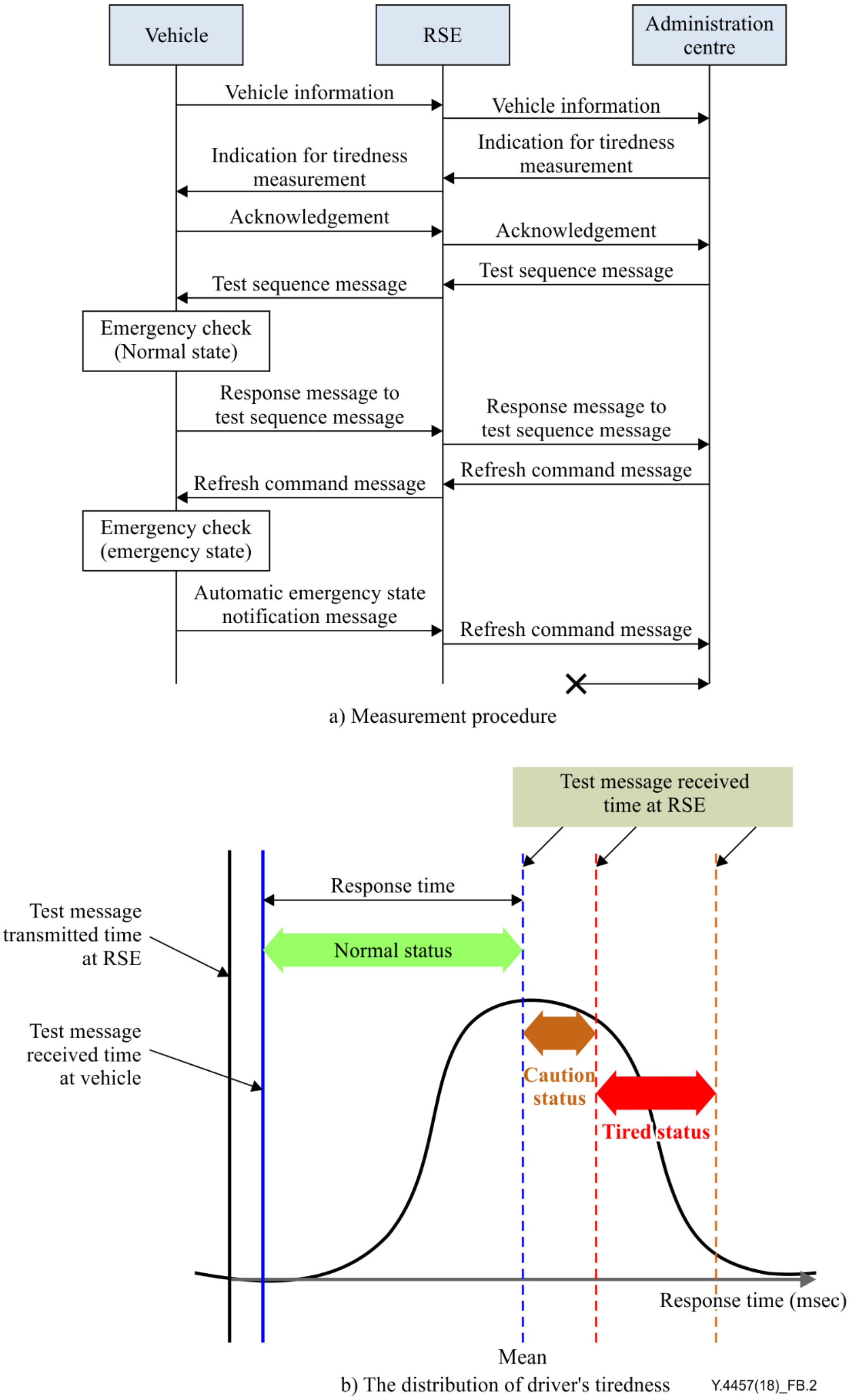

Figure B.2 –The measurement procedure of driver's tiredness

Appendix I

Sensing data pre-processing procedure

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

This appendix describes a sensing data pre-processing procedure based on scenarios of data duplication in vehicles.

I.1 Sensing data pre-processing in a vehicle

In Figure I.1, when vehicles move in locations of near-identical environments, the characteristics of collected sensing data are expected to be identical.

The amount of required processing resources for both vehicles and a transport safety service platform is increased exponentially. Thus pre-processing to minimize transmitting duplicated data is needed.

NOTE – When a vehicle moves on a road with less highway junctions, sensing data collected by each vehicle shows a significantly high correlation (e.g., vehicle speed, outside temperature, road information, GPS information, etc.). Figure I.1 shows scenarios of data duplication in vehicles. When a transport safety service platform (server) collects driving information of a vehicle and all vehicles transmit their own collected data to the transport safety service platform, it leads to the transmission of duplicated data.

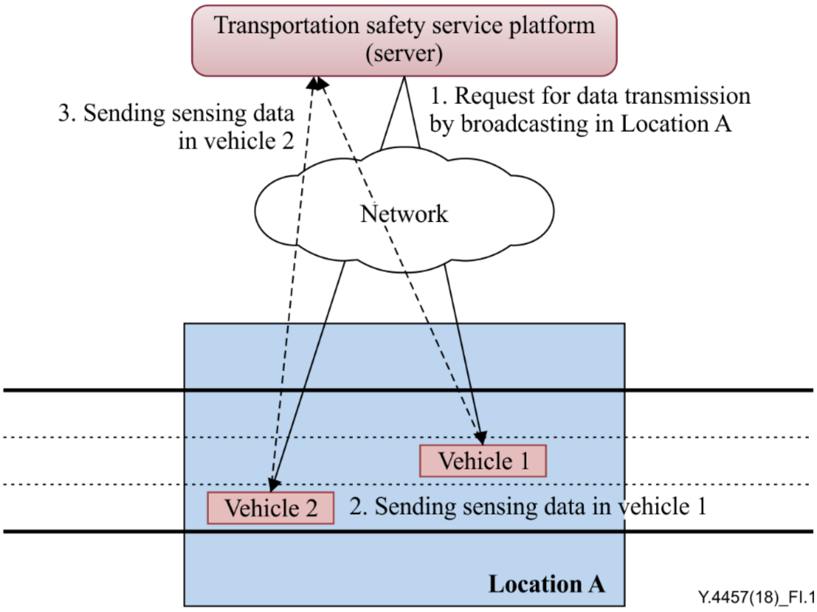

Figure I.1 – Scenarios of data duplication in vehicles

The type of duplication is largely classified by the types of sensing data (e.g., current sensing data, pre-transmitted sensing data and sensing data with adjacent vehicles). In each duplication, pre-processing is implemented and the procedure of duplication pre-processing can be changed as necessary.

I.1.1 Data duplication within current sensing data

When any duplication within current sensing data exists, pre-processing can minimize transmission of duplicated sensing data by transmitting a duplicated data with duplicated times or averaged data (e.g., in case of a lot of unchangeable stationary sensing data).

I.1.2 Data duplication with pre-transmitted sensing data

When there is full duplication between current and pre-transmitted sensing data, it is possible to minimize transmission data volumes by transmitting an indication of full duplication, not current sensing data. When there is also partial duplication between current and pre-transmitted sensing data, it is possible to minimize transmission data volumes by transmitting an indication of partial duplication and partial change, not entire current sensing data.

I.1.3 Data duplication with adjacent vehicles

Sensing data are classified into valid data in a single designated entity (called VD type data) and into valid data in all entities (called VA type data). The type of each sensing datum can be pre-defined. In the case of data transmission in VA type data, it is possible to minimize transmission data volume by substituting sensing data from adjacent vehicles.

NOTE – When sensing data belong to VA type data and are sent for the broadcasting request of the transportation safety service platform (server), the subject vehicle can check for the possibility of substitution from an adjacent vehicle's pre-transmitted sensing data. If an adjacent vehicle is already transmitting sensing data to the transport safety service platform and the transportation safety service platform decides not to collect sensing data from the subject vehicle, it can reduce data transmission by checking the necessity of data transmission. In this case, the transportation safety service platform can notify that data transmission is not needed in response to the pre-broadcasting data transmission request.

The subject vehicle can receive sensing data from adjacent vehicles (e.g., platooning vehicles) using vehicle to vehicle (V2V) communication. If sensing data in an adjacent vehicle are similar to sensing data of the subject vehicle in a predefined scope, the subject vehicle can notify that the adjacent vehicle's already transmitted data can be replaceable. In addition, if there is partial duplication between the subject vehicle and the adjacent vehicle, it is possible to minimize transmission by transmitting the changed part with an indication of partial duplication.

I.2 Sensing data pre-processing in adjacent vehicle

Transportation safety services may be suspended due to a failure of sensor operation. In this case, if an alternative sensor provides sensing data to replace a failed sensor, transportation safety services can be resumed.

NOTE 1 – For example, with V2V communication technology, vehicles can communicate with each other to share vehicle information (e.g., location, sensing data, etc.). If vehicles move in locations of near-identical environments (e.g., platooning vehicles), the characteristics of collected sensing data are expected to be identical.

Scenarios of substituting sensing data using adjacent vehicles are shown in Figure I.2. Vehicles move in locations of near-identical environments. These adjacent vehicles communicate and share each vehicle's information to provide transportation safety services (e.g., forward vehicle collision warning service) using V2V communication capabilities.

NOTE 2 – In Figure I.2, there are left and right vision sensors that capture left and right front image of the vehicle. When right vision sensor R1 in vehicle 1 does not work, a front image of left vision sensor L2 in vehicle 2 can be used instead of a front image of right vision sensor R1. In particular, when vehicles are platooning, a possibility of substitution of sensing data might become higher because platooning vehicles have similar driving conditions.

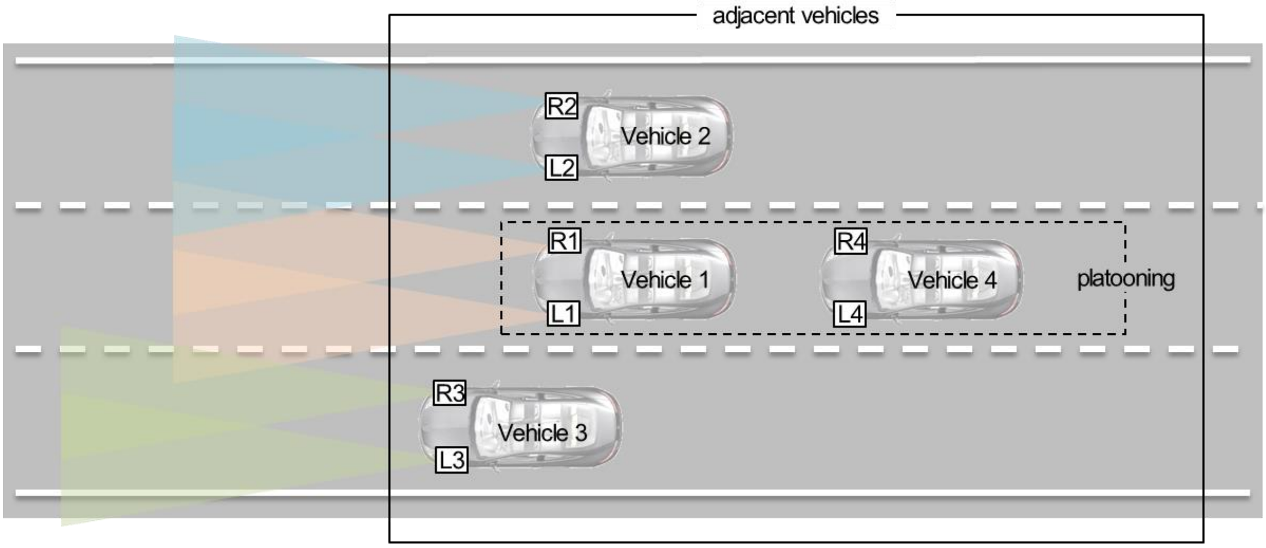

Figure I.2 – Scenarios of substituting sensing data using adjacent vehicle

A substitution procedure from the administration centre to obtain sensing data from adjacent vehicles is shown in Figure I.3. Vehicle 1 and 2 communicate and share status information including location (e.g., lane level location, relative position, etc.). When there is a request for data transmission from the administration centre, vehicle 1 transmits sensing data of left and right vision sensor (L1, R1). In case right vision sensor (R1) does not work, vehicle 1 reports a failure status of right vision sensor (R1) and adjacent vehicle's information (vehicle 2) based on pre-existing V2V communication history. Then the administration centre checks a possibility of sensor substitution of adjacent vehicles and requests data transmission on left vision sensor (L2) in vehicle 2.

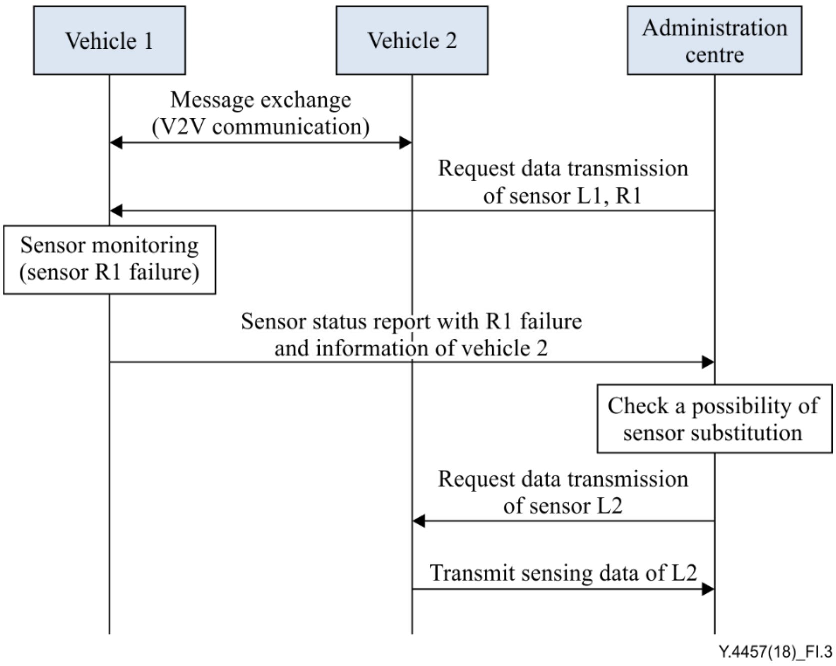

Figure I.3 – Substitution procedure from the administration centre for sensing data using adjacent vehicles

A substitution procedure from the subject vehicle (vehicle 1) requesting for sensing data from adjacent vehicles is shown in Figure I.4. In case right vision sensor (R1) does not work, vehicle 1 checks for a possibility of sensor substitution of the adjacent vehicle (vehicle 2) based on pre-existing V2V communication history and requests data transmission on left vision sensor (L2) in vehicle 2. Then vehicle 1 reports a failure status of right vision sensor (R1) and sensor substitution information including the adjacent vehicle's information with sensing data of left vision sensor (L2).

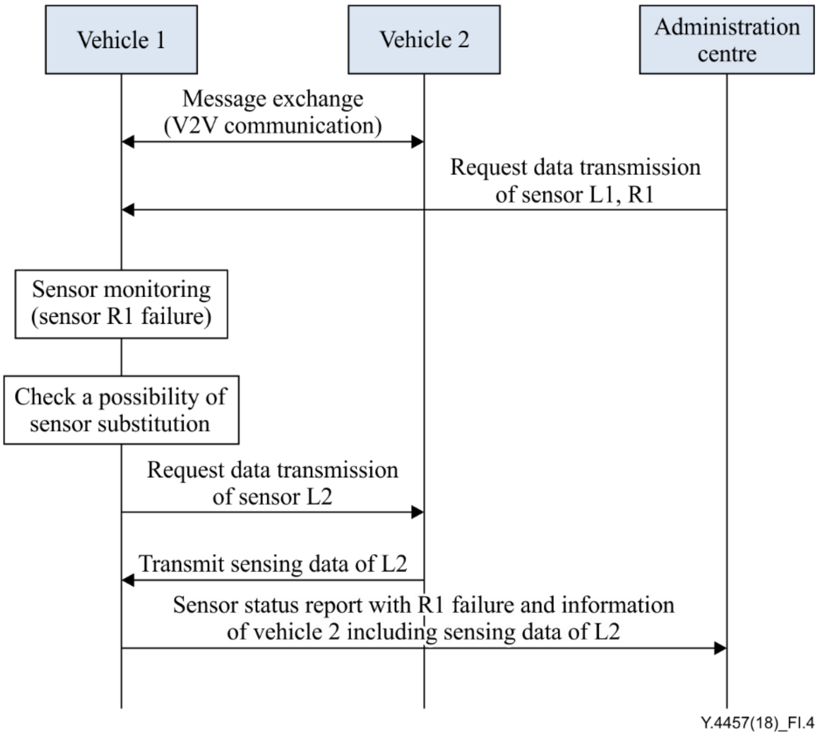

Figure I.4 – Substitution procedure from the subject vehicle for sensing data using adjacent vehicles

Appendix II

Characteristics of transportation application services

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

The characteristics of various application services for road, railway, maritime and air transportation including smart logistics are shown in this appendix.

Table II.1 – Service characteristics for road transportation safety management

Type of service	Required monitoring parameter	Service creation procedure
Traffic accident monitoring service	• Road surface flatness and pot-holes. • Temperature and humidity, freezing status, wind speed on road. • The vibration of bridge and tunnel. • Image of vehicles and infrastructure.	1) Monitoring the traffic flow of vehicles: CCTV image or UAS image. 2) Monitoring the road status: environmental sensor or vehicle built-in sensor using test vehicle or commercial vehicles. 3) Monitoring the accident and detection of accident: create virtual IoT sensor using image and sensing data, and determine the threshold value to detect accident. 4) Disaster simulation: disaster type (fires, traffic crash), the number of death and affected area. 5) Countermeasure: establish an emergency communication network including WSN, connecting with relief centre and hospital.
Traffic jam monitoring service	• Traffic flow. • Road surface flatness and pot-holes.	1) Monitoring the traffic flow of vehicles: CCTV image or UAS image. 2) Monitoring the road status: environmental sensor or vehicle built-in sensor using test vehicle or commercial vehicles. 3) Estimation of traffic jam using simulator. 4) Countermeasure: creation of detour message and announcement for neighbourhood vehicles and related organizations.
Collapse detection service	• Road surface flatness and pot-holes, sinkhole. • Rock slide. • Temperature, and humidity, freezing status, wind speed in road. • The vibration of bridge and tunnel.	1) Monitoring the road status: environmental sensor or vehicle built-in sensor using test vehicle or commercial vehicles. 2) Estimation of collapse using simulator: create prediction model. 3) Detection of collapse. 4) Countermeasure: create alarm message and announcement.

Table II.2 – Service characteristics for railway transportation safety management

Type of service	Required monitoring parameter	Service creation procedure
Train derailment monitoring service	• Rail flatness measured by vibration data. • Railway abnormal status. • Train health status such as temperature and vibration of wheel. • The vibration of bridge and tunnel. • Weather status of railway.	1) Monitoring the train health status: engine components, bogie axle. 2) Monitoring the railway status: environmental weather, vibration of bridge and tunnel. 3) Monitoring the accident and detection: create virtual IoT sensor using various sensing data, and determine the threshold value to detect accident. 4) Disaster simulation: prediction model for the expected life of vehicles and infrastructure, the number of death and affected area. 5) Countermeasure: establish an emergency communication network including WSN, issue an alarm signal for disaster relief activity, broadcasting alarm signal to nearby trains.

Table II.3 – Service characteristics for maritime transportation safety management

Type of service	Required monitoring parameter	Service creation procedure
Marine sinking management service	• The level of ballast water. • Overload state. • Freight binding state. • Weather condition. • Ship repair record.	1) Monitoring the marine health status: engine components, ballast water, overload status, freight binding status, imbalance, capsized state, repair record. 2) Monitoring the environmental conditions: wave height, fog, wind speed, etc. 3) Monitoring the accident and detection of accident: create virtual IoT sensor using various sensing data and determine the threshold value to detect accident, create safety index. 4) Disaster simulation: the number of death and expected time of sinking, affected area in case of oil tanker. 5) Countermeasure: establish an emergency communication network, issue alarm signal for disaster relief activity, broadcasting alarm signal to nearby ships, issue alarm signal for public transportation system.

Table II.4 – Service characteristics for UAS safety service

Type of service	Required monitoring parameter	Service creation procedure
Unlawful UAS flight	• UAS image. • UAS sound. • The radio signal strength for UAS control. • Battery charge state.	1) Monitoring the UAS flying position: analysis of image and sound of UAS, radio signal strength of UAS. 2) Monitoring the status of UAS: battery charge state. 3) Monitoring the accident and health status: monitor the unlawful flying in a prohibited area, monitor the battery charge state of UAS. 4) Countermeasure: announcement of unlawful flying to operator or owner and related organization.

Table II.5 – Service characteristics for smart logistics service

Type of service	Required monitoring parameter	Service creation procedure
Smart logistics service	• Vibration of goods and vehicles. • Temperature and humidity in vehicle. • Delivery delay and timeliness. • Vehicle exchange status during delivery route.	1) Monitoring the health state of vehicle: vibration, overload status, temperature and humidity surrounding goods. 2) Monitoring the flow of logistics: delivery delay, timeliness, vehicle exchange rate. 3) Evaluating the quality of service: the trust index of goods, vehicles and logistics companies. 4) Countermeasure: announcement of trust index, and goods status to owner and public, creation of alarm signal to owner and logistics companies.

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