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

Internet of things and smart cities and communities – Requirements and use cases

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Requirements of transportation safety services including use cases and service scenarios

Recommendation ITU-T Y.4116

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Recommendation ITU-T Y.4116

Requirements of transportation safety services including use cases and service scenarios

Summary

Recommendation ITU-T Y.4116 describes requirements for providing transportation safety services. The use cases and related service scenarios that are used to extract requirements for various IoT services and applications are also described in Recommendation ITU-T Y.4116.

Accidents and disasters caused by the transportation means 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 the transportation infrastructure (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, and save the lives and damage to properties in the case of natural disaster.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Internet of things, platform use case, requirement, service scenario, transportation management centre, transportation safety services, transportation service.

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FOREWORD

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Requirements of transportation safety services including use cases and service scenarios

1 Scope

This Recommendation addresses requirements for providing transportation safety services based on Internet of things (IoT) technologies. These requirements are applicable to various means of transportation, e.g., road, railway, maritime and air.

In this Recommendation, the concepts of transportation safety management according to the processing phases of IoT sensing data and the IoT sensing data necessary for safety management are introduced. An example of a decision-making hierarchy for transportation safety is also described.

The requirements for transportation safety services are described and classified according to the ITU-T IoT reference model [ITU-T Y.4000].

Use cases and related service scenarios used to extract requirements for the various transportation safety services are described in Appendix I.

Appendix II shows the relationship between the requirements provided in clause 7 and the use cases described in Appendix I.

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

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 gateway [ITU-T Y.4101]: A unit in the Internet of things which interconnects the devices with the communication networks. It performs the necessary translation between the protocols used in the communication networks and those used by devices.

3.1.2 Internet of things [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 intelligent transport systems (ITS) [b-ITU-T Y.4407]: ITS is defined as systems utilizing the combination of computers, communications, positioning and automation technologies to improve the safety, management and efficiency of terrestrial transport systems.

3.1.4 sensor [b-ITU-T Y.4105]: An electronic device that senses a physical condition or chemical compound and delivers an electronic signal proportional to the observed characteristic.

3.1.5 sensor node [b-ITU-T Y.4105]: A device consisting of sensor(s) and optional actuator(s) with capabilities of sensed data processing and networking.

3.1.6 thing [ITU-T Y.4000]: With regard to 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.

3.1.7 vehicle gateway platform (VGP) [b-ITU-T F.749.1]: VGP is the collection of ICT hardware and software in a vehicle operating as an open platform to provide an integrated runtime environment for delivering the communications services of a VG. A VGP may also provide higher layer communications services such as interaction with the driver through the driver-vehicle access services and so on. Subsystems dedicated solely to vehicle operation are not considered part of the VGP. Supported applications/services include ITS and infotainment.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms.

3.2.1 logistics satisfaction index: 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.

3.2.2 safety index: 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 1 – As an example of specific transportation infrastructure safety index, the type of road, such as mountain road or urban road, and the road health status, such as irregularity and flatness, pothole and accident status, are evaluated for the road safety index. The road safety index can be adjusted in its evaluation by other parameters such as the type of vehicle and the driver characteristics, such as gender and age.

NOTE 2 – Clause I.1.2 provides information about the safety index.

3.2.3 vehicle: A mean of transportation in air, maritime or surface environments.

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

3.2.4 virtual sensor; soft sensor: 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.

3.2.5 transportation management centre: A centre for the management of transportation, including transportation safety.

NOTE – The main functions of this centre include observation of the safety status of vehicles and transportation infrastructure, and communication with vehicles and transportation infrastructure.

3.2.6 transportation service platform: A platform for transportation service support.

NOTE – The main functions of this platform include monitoring of the safety status of vehicles and transportation infrastructure, and execution of disaster simulations, in order to collaborate with a transportation management centre for transportation safety purposes.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3D	three-Dimensional
CBM	Condition-Based Maintenance
D2D	Device to Device
DMS	Disaster Management System
GIS	Geographic Information System
GPS	Global Positioning System
GTS	Guaranteed Time Slot
IoT	Internet of Things
LPI	Logistics Performance Index
LTE-R	Long-Term Evolution-Railway
M2M	Machine to Machine
MBS	Multicast and Broadcast Service
RAT	Radio Access Technology
UAS	Unmanned Aerial System
VGP	Vehicle Gateway Platform
WLAN	Wireless Local Area Network
WSN	Wireless Sensing Network

5 Conventions

In this Recommendation:

– The expression "**is required to**" indicates a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

– The expression "**is recommended**" indicates a requirement which is recommended but which is not absolutely required. Thus this requirement need not be present to claim conformance.

– The expression "**can optionally**" indicates an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

– The word "**disaster**" refers to a transportation safety-related disaster.

6 The concept of transportation safety management

6.1 Overview of transportation safety management

This clause provides an overview of IoT-based transportation safety management to anticipate disasters and mitigate transportation damage. The transportation safety management is composed by four phases as shown in Figure 1.

The first phase is IoT sensing using devices to monitor not only the operating status of parts of vehicles, such as cars, ships and aircraft, but also the safety status of the transportation infrastructure, such as bridges, tunnels and roads. Also, the loading status of vehicles is monitored by sensors. Because disasters can be caused by surrounding environment parameters, such as bad weather, including snow and freezing conditions, it is necessary to monitor the surrounding environment status of transportation to predict disasters. In order to acquire the sensing data from vehicles, low power sensors are attached to them and these sensors are controllable by things and humans. Virtual IoT sensors, customized for specific monitoring purposes, can be created by combining several physical sensors and other virtual sensors. There are various types of IoT sensing data, relevant examples are listed in Table 1.

The second phase is disaster and transportation safety monitoring. During this phase, disasters that may affect vehicles are monitored in real time by analysing sensing data collected from various IoT devices. Also, the safety index of the transportation infrastructure is estimated by analysing collected IoT sensing data. During the disaster and transportation safety monitoring phase, various types of multimedia content, such as sensing data and images, are analysed.

The third phase is disaster simulation. In this phase, disaster-affected areas and damage are estimated by conflating IoT sensing data from vehicles and transportation infrastructure, and IoT sensing data from the surrounding environment. In this case, the disaster-affected area can be estimated by multidimensional analysis to mitigate the damage from disaster.

The last phase is safety management. This phase determines the countermeasure activities when a disaster has occurred to mitigate transportation damage. There are several countermeasures, such as sending alert signals, providing an emergency communication network, connecting to an emergency service centre. IoT sensors can be controlled from a transportation management centre for certain purposes, such as detailed monitoring and remote calibration. Also, based on monitoring at the transportation management centre and safety index estimation, the centre provides information to transportation infrastructure managers and vehicle operators to mitigate disaster risks, reduce damage and improve safety.

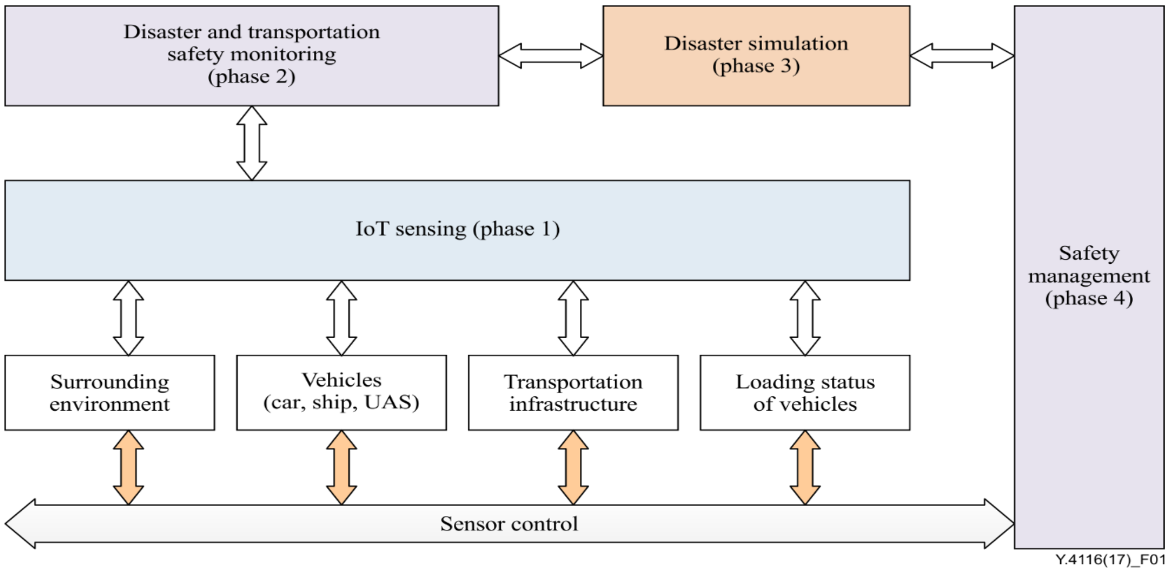

Figure 1 – The concept of transportation safety management

Table 1 – Types of IoT sensing data

Transportation type	Measuring object	Sensing parameter (examples)
Road transportation	Vehicle	Temperature
		Vibration
		Balance
		Inflation pressure
		Humidity
		Weight (cargo capacity)
	Transportation infrastructure (roads, tunnels, bridges)	Safety index
		Pot hole
		Landslide
		Flatness
	Surrounding environment	Road surface state (freezing)
		Weather
		Non-vehicular objects (e.g., pedestrians, fallen trees)
Railway transportation	Train	Temperature
		Vibration
		Humidity (wagon)
		Weight (cargo capacity)
	Transportation infrastructure (rail, tunnels, bridges)	Safety index
	Surrounding environment	Weather
		Rockslide
		Non-vehicular objects (e.g., pedestrians, fallen trees)

Table 1 – Types of IoT sensing data

Transportation type	Measuring object	Sensing parameter (examples)
Maritime transportation	Ship	Temperature
		Vibration
		Humidity
		Loadage
		Ballast water level
	Transportation infrastructure (harbour facility)	Safety index
	Surrounding environment	Weather
		Water height
Air transportation	Unmanned Aerial Vehicle	Altitude
		Course
		Power level
		Payload
	Surrounding environment	Weather

6.2 The hierarchy of transportation safety management

As shown in Figure 2, a transportation safety management system includes open interfaces to communicate with vehicles [e.g., with an in-vehicle wireless sensing network (WSN)], a wideband radio network installed in the surrounding transportation infrastructure (e.g., an ITS-based wideband radio network for road transportation, a wideband radio network based on long-term evolution-railway (LTE-R) for railway transportation, e-navigation-based wideband radio network for marine transportation), a transportation service platform and a transportation management centre. In order to provide transportation safety services, sensors continuously measure safety-related parameters of vehicles and transportation infrastructure, and sensing data are analysed to detect and predict disasters.

The transportation service platform monitors transportation safety relevant conditions and parameters, performs disaster simulations in order to collaborate with the transportation management centre for transportation safety purposes, and decides the threshold values for the prediction and detection of disaster.

The transportation management centre monitors the safety status of vehicles and transportation infrastructure, and influences the operations of vehicles and infrastructure, by collaborating with the transportation service platform, including the generation of alarms if the status of vehicles and transportation infrastructure is abnormal.

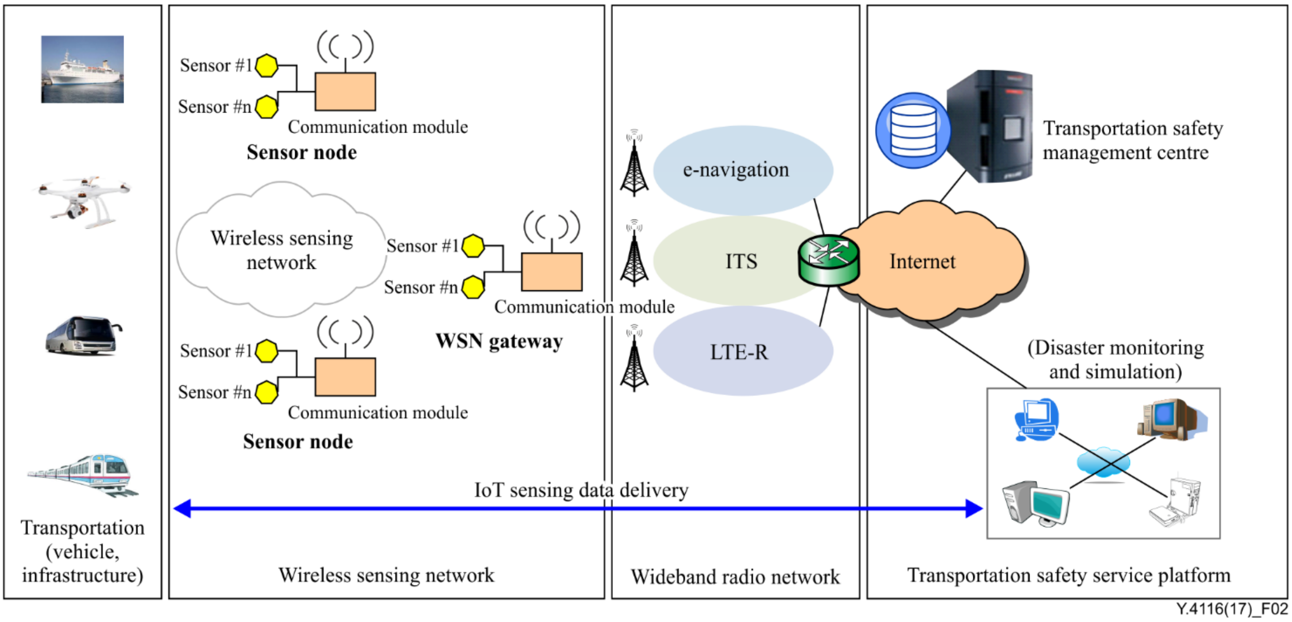

Figure 2 – System structure for transportation safety management

Since vehicles move regularly, determination of the safety status of vehicles in a timely manner in order to anticipate disasters is required.

Appropriate processing technology should be used for transportation safety management.

As an example, Figure 3 shows a decision-making process for transportation safety management based on distributed processing technology.

Vehicles may process and compare sensing data to threshold values. Sensing data from vehicles and transportation infrastructure are delivered to the transportation safety service platform.

The transportation safety service platform generates virtual sensors and safety indexes for precise decision-making, i.e. the transportation safety service platform generates threshold values for making more accurate safety decisions based on big data analytics. The threshold values generated by the transportation safety service platform can then be delivered to vehicles in order to adjust local decision-making as appropriate, as shown in Figure 3.

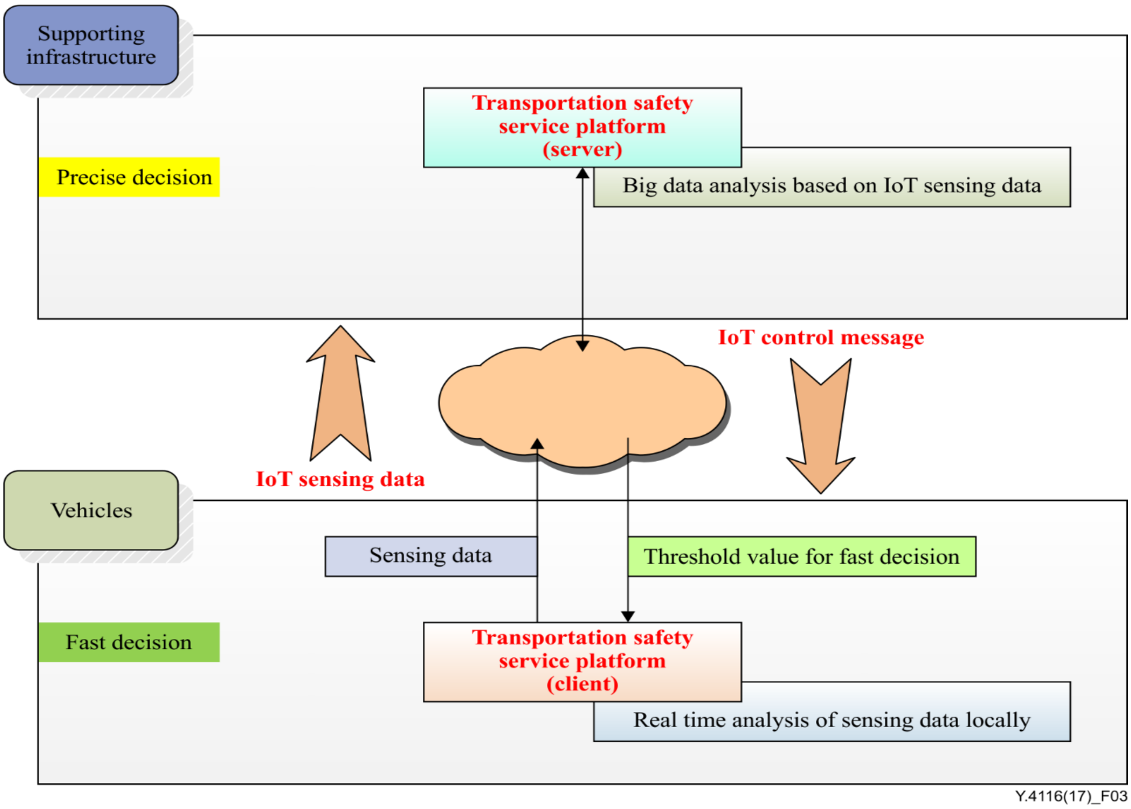

Figure 3 – Example of decision-making based on distributed processing technology

7 Requirements for transportation safety services

This clause provides a list of basic requirements for transportation safety services with respect to different transportation disaster types and related characteristics of safety management.

Examples of transportation disaster types and related characteristics of safety management are listed in Table 2.

Table 2 – Characteristics of safety management for different transportation disaster types

Type of transportation	Type of disaster	Cause of disaster	The characteristics of safety management
Road	– Car collision – Car overturn – Traffic injury	Abnormal status of vehicle	– Sources of abnormality: engine and driving parts – Manageable and predictable
		Abnormal status of transportation infrastructure	– Sources of abnormality: road, bridge, tunnel – Manageable and predictable
		Bad weather conditions	– Kinds of bad weather: freeze, fog, rain – Unmanageable and predictable
		Driver tiredness	– Tiredness phenomena: sleepiness, de-concentration – Manageable and predictable condition: driver's sleepiness – Unmanageable condition: driver's de-concentration

Table 2 – Characteristics of safety management for different transportation disaster types

Type of transportation	Type of disaster	Cause of disaster	The characteristics of safety management
Railway	– Train collision – Train derailment – Traffic injury	Abnormal status of train	– Sources of abnormality: engine of locomotive, bogie – Manageable and predictable
		Abnormal status of transportation infrastructure	– Sources of abnormality: railway, bridge, tunnel – Manageable and predictable
		Bad weather conditions	– Kinds of bad weather: freeze, fog, rain – Unmanageable and predictable
		Driver tiredness	– Tiredness phenomena: sleepiness, de-concentration – Manageable and predictable condition: driver's sleepiness
Maritime	– Ship collision – Ship sinking	Abnormal status of ship	– Sources of abnormality: engine and equipment for a voyage – Manageable and predictable
		Bad weather conditions	– Kinds of bad weather: wind and waves, storm – Unmanageable and predictable
		Mate's tiredness	– Tiredness phenomena: sleepiness, de-concentration – Manageable and predictable condition: mate's sleepiness
Air [unmanned aerial system (UAS)]	– Abnormal flying – UAS crash	Abnormal status of UAS	– Sources of abnormality: engine and driving parts – Manageable and predictable
		Bad weather conditions	– Kinds of bad weather: wind and rain, storm – Unmanageable and predictable
		Pilot condition	– Tiredness phenomena: carelessness – Manageable

7.1 Sensor requirements

1) A sensor is required to be controllable by humans or things.

2) Sensor calibration by remote is recommended.

3) A sensor is recommended to be operated with minimum power to make the use of the power source generated by the energy harvester attached to a vehicle sufficient for sensor operation, as well as extending operational life and reducing maintenance cost.

4) A sensor node can consist of multiple sensors and a communication module. It is recommended that an open interface be provided to manage the various sensors and to reduce operational and maintenance costs.

5) The sensing period of a sensor is recommended to be adjustable according to the power status of the sensor node in order to save sensor power.

6) A sensor is recommended to provide measured data with timing information.

7) In the case of a wireless sensor network, the sensing period and transmission period of a sensor are recommended to be adjustable according to the channel capacity of the wireless sensor network in order to ensure sustainability of the sensing operation.

7.2 IoT sensing network requirements

1) Sensors are recommended to support interconnectivity through a wireline or wireless network, enabling device to device (D2D) or machine to machine (M2M) communication.

2) Sensors are recommended to enable cooperation with each other through a sensing network in order to support precise monitoring (e.g., for the purpose of anticipating disasters).

3) An IoT sensing network is recommended to support connectivity to external heterogeneous networks, such as wireless local area networks (WLANs) and mobile networks, in order to enable service coverage extensions.

4) An IoT sensing network is required to enable connectivity to a gateway [ITU-T Y.4101], which supports IP and non-IP addressing schemes.

5) An IoT sensing network is recommended to support multicasting service for sensing data and control messages in order to decrease delay latency and to mitigate sensing network interference.

6) An IoT sensing network is recommended to extend a service coverage area using dedicated multi-hop channel technology, e.g., based on a dedicated channel as specified in [b-IEEE 802.15.4] or other radio access technologies, such as WLAN, in the case of a multi-radio access technology (multi-RAT) environment.

7) An IoT sensing network is recommended to be fault tolerant, including delay tolerance, in order that, in case of network disruption, sensing data from affected areas can still be collected.

7.3 IoT sensing data delivery requirements

1) IoT sensing data are recommended to be compressed before transmission to reduce network load and, in case of wireless network, to decrease interference.

2) IoT sensing data are recommended to be protected from unauthorized access.

3) IoT sensing data are recommended to be transmitted with timing information, e.g., in the case of aggregation of various sensing data delivered from different networks.

4) IoT sensing data are recommended to be delivered using standard formats, e.g., for the purpose of creating multiple application services using those data.

5) The interface between a road vehicle and the transportation safety service platform is recommended to support standardized Intelligent Transportation Systems (ITS) technologies [b-ITU-T Y.4407] to deliver IoT sensing data.

6) The interface between a train and the transportation safety service platform is recommended to support standardized LTE-R [b-3GPP release 11] technologies to deliver IoT sensing data.

7) The interface between a ship and the transportation safety service platform is recommended to support standardized e-navigation technologies [b-IMO] to deliver IoT sensing data.

7.4 Transportation safety-related disaster monitoring requirements

1) In order to mitigate risks, it is required to accurately anticipate and detect disasters.

NOTE 1 – IoT sensing data as described in Table 1 and images generated from CCTV or cameras may help in disaster prediction and detection (e.g., sensing data values above thresholds can be considered as indicators for the prediction and detection of disaster).

2) The threshold values for estimation of anticipatory signs and disaster detection are recommended to be accessible for timely processing in vehicles.

NOTE 2 – As an example, the transportation safety service platform may generate threshold values and deliver them to vehicles.

3) IoT sensing data from vehicles and transportation infrastructure, as well as offline data, such as climate and disaster history, can optionally be used to increase the ability to anticipate disasters with high accuracy in real time.

4) In order to reduce damage from disasters, collaboration among multiple IoT devices in vehicles and transportation infrastructure can optionally be realized to increase reliability and timeliness of disaster detection.

NOTE 3 – The accuracy and reliability of disaster detection may be impacted by the accuracy of IoT sensing data, types of sensing data, and appropriate combination of multiple threshold values.

7.5 Maintenance requirements of transportation infrastructure and vehicles

1) IoT transportation safety services are required to provide IoT-based information in order to manage transportation infrastructure and vehicle safety.

2) Safety indexes created from IoT sensing data are recommended to be used in order to analyse transportation infrastructure and vehicle safety status.

3) Safety indexes are recommended to be used to generate appropriate maintenance actions for transportation infrastructure.

4) Transportation infrastructure safety modelling that classifies the transportation infrastructure according to its characteristics and determines points where IoT sensors have to be placed is recommended to estimate the health status of transportation infrastructure, predict disasters and establish maintenance strategy.

5) It is recommended that transportation safety services and vehicle work together to provide the driver with early warning notifications of vehicle abnormal status. Transportation safety services can optionally help the driver to do maintenance off line.

6) It is recommended that the transportation safety services and vehicle work together to provide the driver with forecasts of potentially abnormal safety status of vehicle. The transportation safety services can optionally help the vehicle manufacturer to enhance the vehicle's safety functions and performance.

7) It is recommended that vehicles do the self-check automatically on fault triggers, event triggers, environment triggers, as well as according to the predefined schedule such as check period, check date, and manual check.

8) It is recommended that vehicles do the online check to get comprehensive and professional examinations when unrecoverable faults have occurred in the self-check.

NOTE – The online check, triggered by these faults, can be run on a periodic basis or non-periodic basis.

9) It is recommended that vehicles do the appropriate online maintenance if problems have been found in the online check.

7.6 Disaster simulation requirements

1) Disaster simulations based on IoT sensing data from vehicles and transportation infrastructure can be optionally used to increase the ability of disaster occurrence prediction and disaster type prediction, and, in case of disaster occurrence, to increase the ability of affected disaster area estimation for exact countermeasures.

2) In order to improve accuracy of disaster simulation, combination of relevant IoT sensing data can be optionally used (e.g., from vehicles, transportation infrastructure and the surrounding environment).

3) Simulations of the various transportation disaster types (e.g., crash because of bad weather, vehicle overturn and sinking) are required to prepare appropriate countermeasures.

4) It is required to estimate the propagation velocity and area affected by dangerous materials in the case of accidents from vehicles carrying them, such as hydrofluoric acid or sulfuric acid.

5) It is required to estimate the area affected by disaster by simulation.

NOTE 1 – Information from spatiotemporal data modelling based on a geographic information system (GIS) and three-dimensional (3D) space information can optionally be used to improve the accuracy of estimation.

6) In order to improve the ability to anticipate disasters, a disaster occurrence estimation model is recommended to be generated.

NOTE 2 – IoT sensing data can be optionally used in support of modelling.

7.7 Management requirements of transportation safety services

1) It is recommended to manage transportation safety comprehensively, including consideration of both vehicles and transportation infrastructure.

2) In order to efficiently manage transportation safety, transportation management is recommended to collect and use current IoT sensing data, as well as relevant and appropriate accident history data and maintenance history data.

3) In order to manage the maintenance record of vehicles, it is recommended that a vehicle repair centre automatically collect vehicle identification and repair history status when a vehicle enters the centre.

4) In order to avoid accidents caused by driver tiredness, it is recommended that driver tiredness be monitored in real time while driving and appropriate action taken.

5) When measuring tiredness, it is recommended that drivers collaborate with the transportation management centre in terms of providing relevant information about their tiredness and taking appropriate action.

7.8 Application service requirements of transportation safety

1) It is recommended that composition of IoT sensing data be enabled for the creation of application services.

2) For transportation safety service provisioning, relevant IoT sensing data (e.g., from vehicles and transportation infrastructure) are recommended to be composed to create virtual IoT sensors, as these can reduce the number of required physical sensors and their maintenance costs.

3) In order to reduce the disaster damage risk, the establishment of emergency network facilities (e.g., wireless sensor networks) is recommended as countermeasure.

4) For transportation safety service provisioning, analysis of relevant IoT sensing data (e.g., from train bogie and electric equipment, and transportation infrastructure) is recommended to generate a safety index in real time.

5) Operation of condition-based maintenance (CBM) technology is recommended using IoT sensing data.

NOTE – CBM monitors the actual conditions of vehicles and transportation infrastructure to decide what maintenance needs to be done. It may help disaster anticipation.

6) In order to create smart logistics services, conflation of relevant IoT sensing data (e.g., from vehicle and transportation infrastructure) is recommended in order to produce a logistics satisfaction index.

7) In order to calculate a logistics satisfaction index, use of historical delivery data from goods and delivery companies is recommended.

Appendix I

Use cases and service scenarios for transportation safety services

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

This appendix describes various use cases illustrating the application service based on transportation safety services using IoT technologies.

I.1 Transportation safety management services

I.1.1 Transportation status-monitoring service

Safety assurance and cost effective management are important for all means of transportation, including car, bus, train and ship, in order to increase traffic capacity and provide fast transportation.

Figure I.1 shows the management of different transportation services via a unified approach. This approach is particularly appropriate because different transportation services may be complementary and affect each other. An example scenario for such complementary services is one in which, because of a bus accident, passengers transfer from a bus to a train.

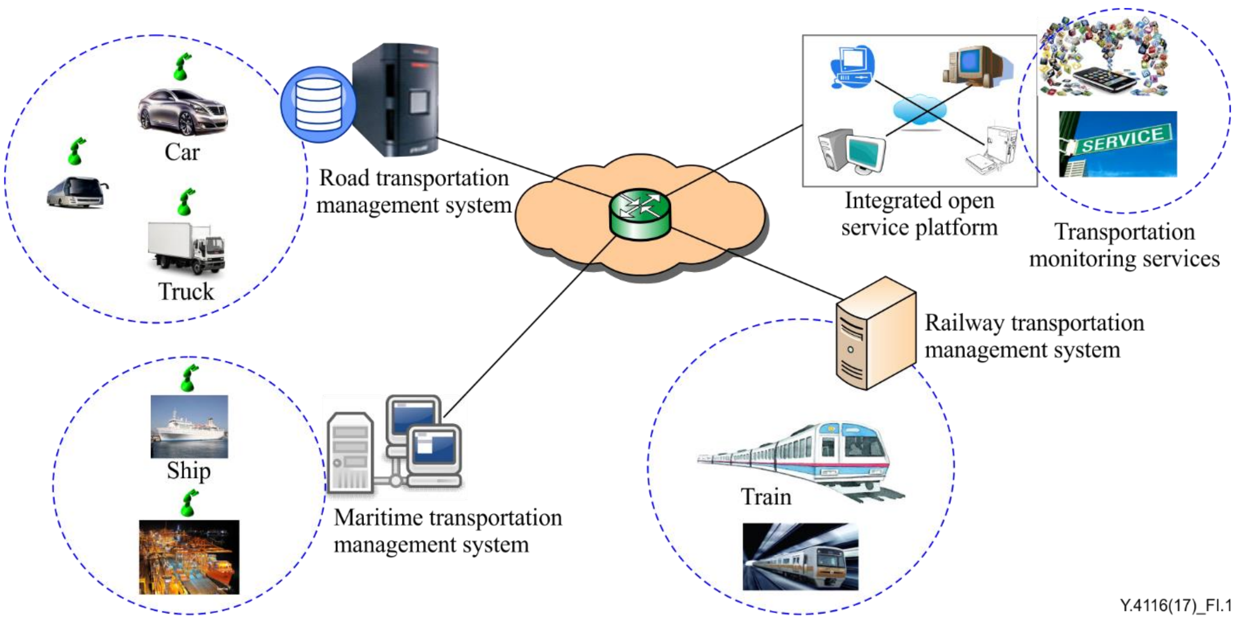

Figure I.1 – Transportation status-monitoring service

In order to integrate all kinds of transportation information, management systems for road transportation, railway transportation and marine transportation are connected to an integrated open service platform.

The transportation status-monitoring service provides the status of a transportation service for people in general, as well as for expert entities, such as transportation companies and disaster management centres.

The transportation status-monitoring service provides expert entities with the status parameters of vehicles, such as temperature and vibration of vehicles, either in operating time or down time. In the case of a transportation status-monitoring service for expert entities, if there are some problems with vehicles, alert signals are generated to inform expert entities and related entities. The users of the transportation status-monitoring service (people in general or expert entities) can access status parameters at any time and place (e.g., using a PC or a smartphone).

Tables I.1 and I.2 summarize the information offered by the transportation status-monitoring service to people in general and expert entities, respectively.

Table I.1 – Transportation information for people in general

Vehicle type	Vehicle ID	Time tables		Vehicle status information		
		Departure	Arrival	Current location	Timeliness	Accidents
Bus	100	10:30 (A place)	14:30 (B place)	C place	Delay:0 min	Normal
	150	10:30 (K place)	14:30 (M place)	L place	Delay:5 min	Crash
Train	K-101	10:00 (X place)	16:30 (Z place)	Y place	Delay:2 min	Normal
Ship	S-101	16:00 (D place)	18:30 (F place)	D place	Delay:2 min	Normal

Table I.2 – Transportation information for expert entities

Vehicle type	Vehicle ID	Time tables		Vehicle status information			Health status of driving equipment	
		Departure	Arrival	Current location	Timeliness	Acci-dents	Vibration value	Temper-ature
Bus	100	10:30 (A place)	14:30 (B place)	C place	Delay: 0 min	Normal	2*g*	68°C
	150	10:30 (K place)	14:30 (M place)	L place	Delay: 5 min	Crash	2.5*g*	60°C
Train	K-101	10:00 (X place)	16:30 (Z place)	Y place	Delay: 2 min	Normal	1.6*g*	65°C

In order to satisfy transportation status-monitoring service requirements, low power consumption IoT sensors are installed on vehicles to monitor various vehicle parameters (e.g., from engine, axle and pump). In some cases, IoT sensors may also connect automatically to each other. Measurement data are delivered to the transportation management system(s) through wireless networks.

The integrated open service platform may also use these IoT sensing data for other application services. In addition, the IoT sensing data may be made accessible to the public through the integrated open service platform, e.g., for third party applications.

The following are some application services for people and expert entities that may be provided in addition to the basic transportation status-monitoring service.

1) Transportation information service for people:
   - according to the type of transportation, vehicle identity and other vehicle-related information, such as current location and estimated arrival time at a station, are provided to people;
   - transportation recommendations are provided concerning optimal means or alternative means of transportation;

2) Transportation information service for expert entities:

- in addition to the information offered by the transportation information service to people in general, the health status information of driving equipment is provided to expert entities for transportation safety purposes;
- if the health status of the driving equipment provided by the transportation information service is abnormal, the expert entities analyse the seriousness of the issue – if the seriousness is beyond tolerable limits, alternative means of transportation are provided.

I.1.2 Road safety management service

Among man-made disasters, those involving public transportation have more significant impact in terms of loss of human life than natural disasters. In order to decrease the damage caused by disasters, it is important to estimate them accurately and reliably using IoT sensing data from vehicles and transportation infrastructure. Since transportation infrastructure safety as well as transportation vehicles are affected by disasters, it is necessary to use IoT sensing data from both these sources in disaster estimation. IoT sensors from vehicles and transportation infrastructure can together help to protect humans and properties from disasters.

Disaster management systems (DMSs) monitor transportation disasters in real time. When a disaster occurs, the areas affected should be rapidly simulated, including possible usage of virtual IoT sensors, to improve the ability to anticipate and detect future disasters.

NOTE – Virtual IoT sensors can easily monitor several kinds of parameters by combining various sensing data.

Also, a disaster countermeasure service using IoT technology should be provided as soon as possible to mitigate damage. Figure I.2 shows the road safety management service model to mitigate disaster damage. In this model, various capabilities or facilities are implemented.

1) Disaster monitoring

- Various sensors are installed in-vehicle to monitor parameters, e.g., vibration and temperature of bogie and engine. Some sensors are installed to monitor the status of engine, e.g., load, pressure, revolutions per minute.
- Also, various sensors are installed in transportation infrastructure, such as tunnels, roads and bridges, to monitor transportation infrastructure parameters, e.g., vibration and flatness of road, freezing conditions and fog.
- Each sensor in-vehicle is connected to a VGP [b-ITU-T F.749.1] to deliver sensing data to the destination road DMS using wireless links. Some sensors can be connected by D2D link.
- The VGP can detect a disaster by comparing the sensing data with threshold values. These threshold values for disaster detection are delivered to the VGP from the DMS, which can be located remotely from vehicles. The DMS generates threshold values for disaster detection via analysis of IoT sensing data that are delivered from vehicles and transportation infrastructure.
- Several sensors can cooperate with each other to create virtual IoT sensors or to obtain more precise measurements.
- As driver tiredness can generate accidents, monitoring is necessary. To do this, a camera or bio-sensors are installed around the driver seat. Also, driver tiredness can be measured by actuators – attached to the wheels – that reply to test messages sent from roadside equipment to the driver.
- Sensing data can be compressed to reduce the transmission rate before their delivery to the DMS, e.g., the moving average value of sensing data from vehicles can be delivered instead of raw data.

2) Disaster simulation for disaster estimation

– Disaster simulation can be done to improve the ability to predict disasters using IoT sensing data.

– In order to increase prediction accuracy, virtual IoT sensors can be generated combining various IoT sensing data according to the timing information embedded in sensing data as metadata.

– When a disaster has occurred, the disaster-affected area can be simulated to avoid secondary accidents and to decrease accidental damage. The disaster-affected area can be classified according to disaster impact.

3) Emergency communication facilities for alerting

– Emergency communication facilities should be installed as soon as possible in order to monitor the status of accidents.

– If there is no permanent backhaul link, delay tolerant technologies can be used to interconnect a WSN with the wireless network or the Internet.

– UASs provide emergency communication links to counteract disaster.

– An emergency WSN can be installed to monitor the scene of an accident.

4) Disaster countermeasures for saving lives and reducing damage

– In order to save lives and reduce disaster damage, various countermeasures can be provided, such as reporting to disaster management centres and calling hospitals.

– For traffic accidents, detour information can be provided to vehicles in the vicinity.

5) Safety maintenance and disaster prevention

– In order to maintain vehicles and transportation infrastructure, a safety index can be generated using various IoT sensing data. An example of safety index calculation according to IoT sensing data is the following:

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

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;

D_i : offset value from SS_i_max;

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

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

– In order to improve the ability to avoid disasters, vehicles and transportation infrastructure should be inspected regularly. The inspection period can be adjusted according to their safety status.

– When a sign of an emergency is identified, this information should be broadcast to the relevant people and organizations.

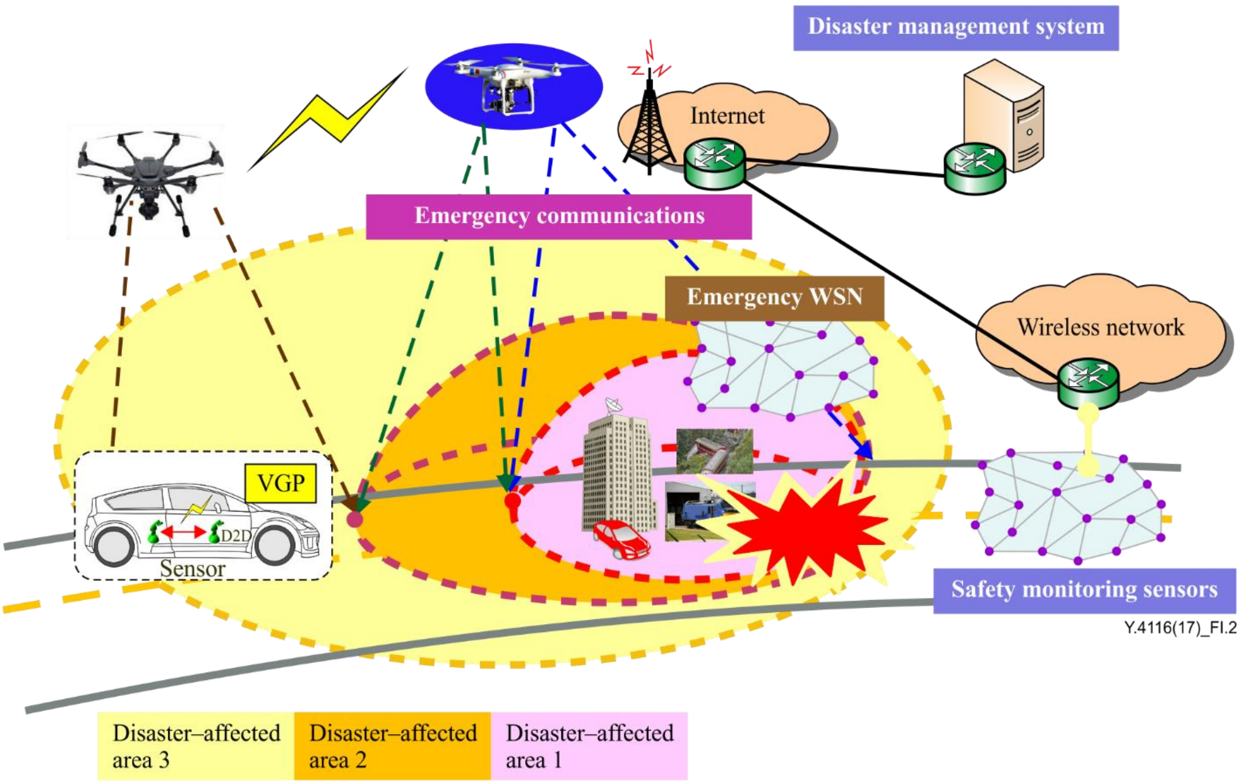

Figure I.2 – Road safety management service model

I.1.3 Train safety management service

Nowadays, as the speed of trains increases, the importance of train safety cannot be underestimated. Accidents involving high-speed trains induce serious damage to lives and property. In order to avoid train accidents, a safety management service based on sensing technology can be used, as shown in Figure I.3.

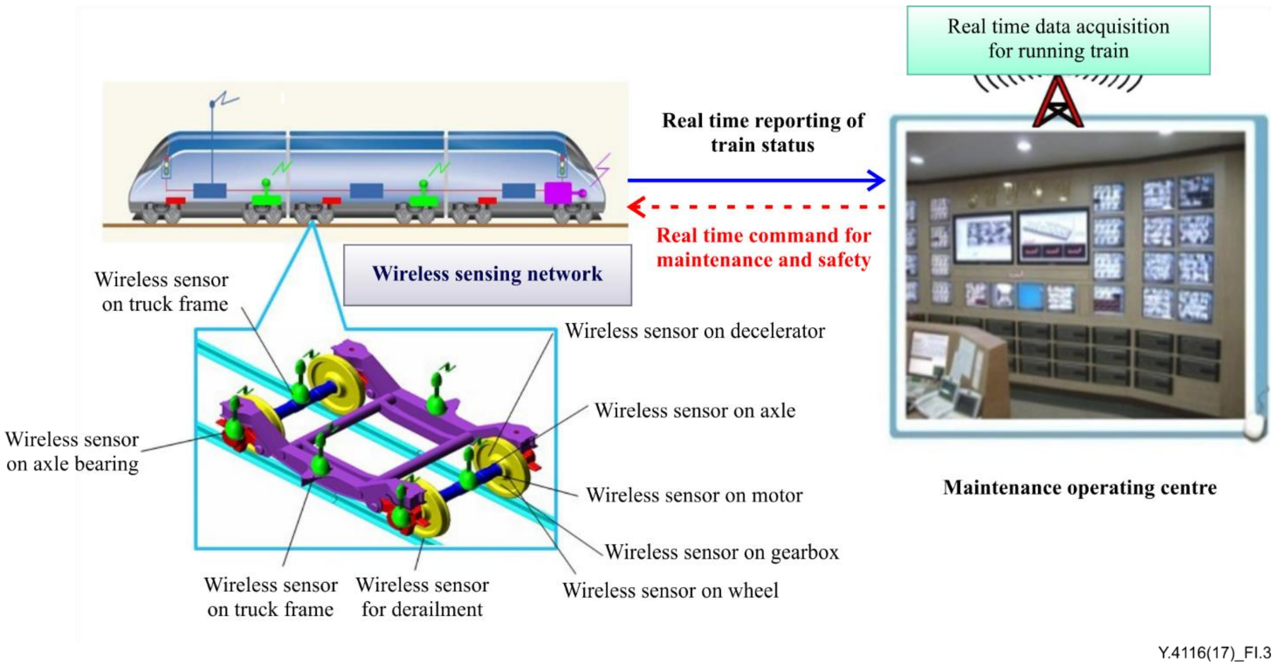

Figure I.3 – Train safety management service model

In this model, the operating status of the locomotive, as well as passenger and cargo cars, is continuously monitored and data are delivered to the maintenance operating centre in order to predict and detect disasters. Using this technology, train safety can be enhanced and maintenance costs reduced.

Figure I.4 provides details of the WSN topology for a train safety management service.

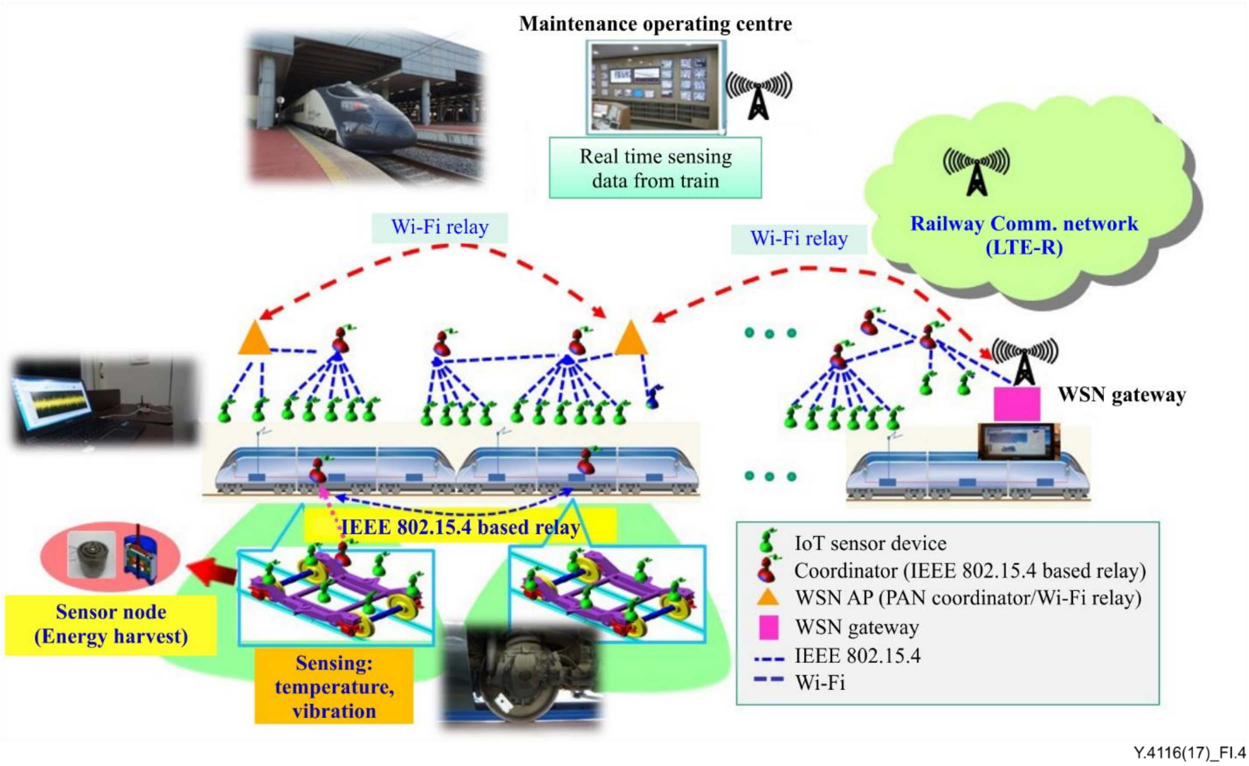

Figure I.4 – Wireless sensing network topology for train safety management service

In this model, various capabilities or facilities are implemented.

1) Disaster monitoring

– Low-power consumption IoT sensors are attached near the train wheels to continuously monitor temperature and vibrations in order to prevent derailment.

– In the case of legacy trains or freight trains, energy harvester power can be used, as there is no power supply for IoT sensors attached near to the wheels.

– For IoT sensors powered by energy harvester power in particular, the sensing and transmission time intervals can be adjusted to extend the sensor operating period and reduce the interference signal.

2) Wireless sensing network

– As the coverage area of one WSN would roughly correspond to the length of one train wagon, in order to cover the whole length of a train it is usually required to extend the coverage area of WSNs using appropriate radio access technologies such as Wi-Fi, as shown in Figure I.4. In the example shown in Figure I.4, low power sensing technology [b-IEEE 802.15.4] is used within the train wagons for sensing and Wi-Fi is used as an IP relay to deliver sensing data to the WSN gateway [ITU-T Y.4101] located in the locomotive.

– Interference mitigation technology is required to maintain the quality of communications.

– Because of the large number of sensors due to the train length, it is recommended to apply multicast and broadcast service (MBS) in WSNs in order to decrease latency and to mitigate interference signal (e.g., an MBS can be implemented using a dedicated channel [guaranteed time slot (GTS)] [b-IEEE 802.15.4]).

– The service coverage area of WSNs can be extended using multi-hop relays based on a GTS channel.

3) Sensing data delivery network

– IoT sensing data are transmitted to the maintenance operating centre through a WSN and wireless network. LTE-R [b-3GPP release 11] may be used as wireless network technology as shown in Figure I.4, although other technologies may be also used (e.g., Wi-Fi).

– WSNs are connected to the wireless network via a WSN gateway located in the locomotive.

– A WSN gateway can manage all sensors in the train, and the (normal or abnormal) status of all sensors is registered in the WSN gateway.

– Since the volume of IoT sensing data is large, it is better to reduce the transmission data rate by pre-processing data according to the characteristics of the measurement data, e.g., the average value of raw sensing data can be transmitted instead of the raw sensing data itself.

4) Disaster detection

– IoT sensing data are analysed to detect disasters using pre-defined threshold values. Detection can be realized by IoT sensors or a WSN gateway.

– Threshold values are determined by the maintenance operating centre using sensing data from the train. These threshold values are transmitted to the IoT sensors or WSN gateway.

– When an abnormal status of a train is detected, an alarm message has to be generated automatically and transmitted to the locomotive driver as soon as possible.

5) Disaster simulation

– Disaster simulation can be done to improve the ability to predict disasters and the expected operating life of the train using IoT sensing data.

– In order to increase the accuracy of the prediction rate, virtual IoT sensors can be generated combining various IoT sensing data according to the timing information that is embedded in the sensing data as metadata.

– When a disaster occurs, the affected area can be simulated to avoid secondary accidents and to decrease accidental damage.

6) Disaster countermeasure and maintenance

– In case of abnormal status, WSN gateway installed in locomotive alerts the driver to counteract this situation.

– After the maintenance operating centre detects the abnormal status of the train, it determines the various countermeasures.

– When an abnormal status of wheels is detected, since the IoT technology enables the identification of the position of sensors, it is easy to find the damaged wheel of the train during the repair process. Therefore, maintenance cost can be reduced.

– If the maintenance operating centre recognizes the accident, an alarm message has to be broadcasted to the relevant organizations and nearby trains.

– In order to avoid disasters, it is necessary to maintain trains and infrastructure according to the safety index indicating the health status based on IoT sensing data.

NOTE – Maintenance can happen regularly or occasionally depending on the health status.

I.2 Intelligent traffic management service

This service provides traffic information in real time by cooperative communication in the case of an ITS [b-ITU-T Y.4407] environment between road vehicle and roadside equipment, as well as road vehicle to road vehicle. Traffic flows can be analysed by using the vehicle IoT sensors and the transportation infrastructure IoT sensors. According to the traffic situation, the driver can automatically receive driving recommendations from the traffic control centre such as detour route information. It is possible that driverless cars can enjoy safe driving without accidents using IoT sensing data. Also, people can choose appropriate means of transportation based on IoT data.

To satisfy intelligent traffic management service requirements, IoT sensing data from vehicle and roadside equipment can be automatically combined.

There are several kinds of intelligent traffic management service as follows.

1) Smart route guidance service
   - This service provides the optimal route based on traffic status and road conditions by interaction with vehicles and roadside equipment. Road conditions, such as pot-holes and road surface roughness, are monitored by IoT sensors installed in vehicles.
   - The traffic control centre analyses the traffic status according to the IoT sensing data and the type of road transportation (e.g., public transportation and private cars), and determines the optimal route from current location to destination. For example, according to traffic jam or road surface status measured by vehicle IoT sensors and roadside equipment sensors, a detour route can be provided to the driver, as shown in Figure I.5.
   - In the case of traffic jams or accidents, a transport transfer service can be provided to passengers.
   - Also, this service enables a senior citizen to drive safely by providing guidance based on characteristics.
2) Dangerous goods transportation service
   - It is very dangerous for vehicles transporting dangerous goods to pass through residential areas because of the potential impact in the case of accident.
   - This service provides safe routes to the driver by analysing IoTsensing and location data. The IoT sensing data may include the weight status of the vehicle, the vibration status of vehicle, the type of transported goods and driver characteristics.
   - When an accident occurs involving vehicles carrying dangerous goods, dangerous chemical materials, such as hydrofluoric acid and sulfuric acid, may leak and spread into the surrounding area.
   - After the detection of an accident involving vehicles carrying dangerous goods by analysing IoT sensing data, performance of a simulation to estimate the damage and the area affected, based on 3D spatial data and environmental parameters, such as wind speed, temperature and humidity, is recommended within a limited time following the disaster using a GIS [b-GIS].
   - In order to avoid damage, warning messages are broadcast to vehicles in the vicinity within a limited time after the disaster.

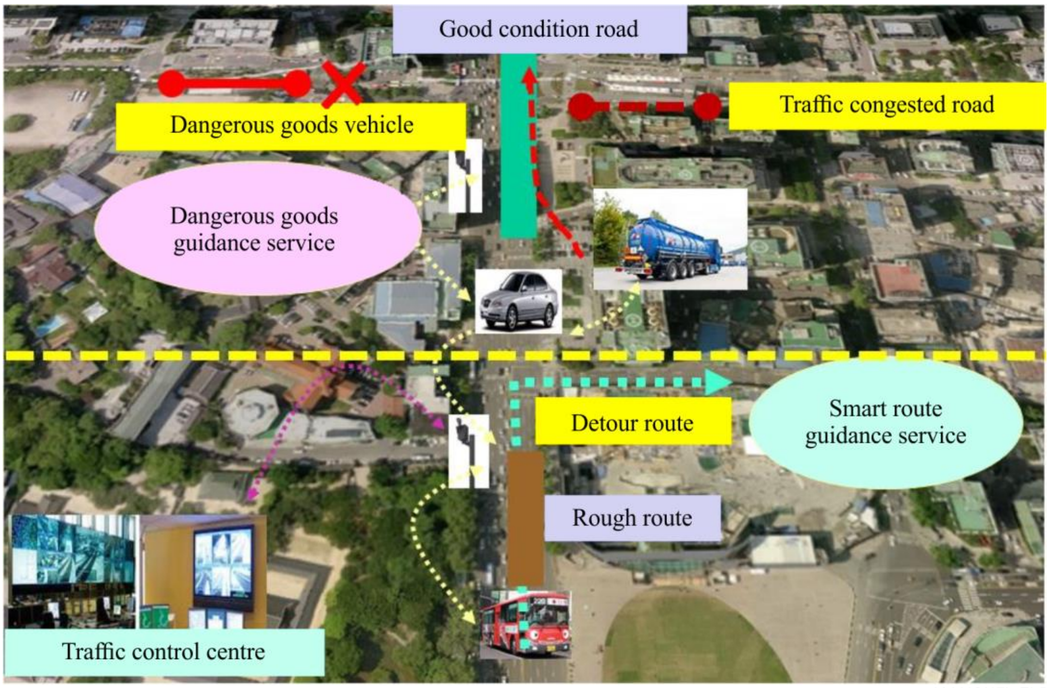

Figure I.5 – The concept of intelligent traffic management service

I.3 Smart logistics service

Smart logistics management, making use of transportation sensing information for goods delivery policies ensuring fast delivery and appropriate maintenance conditions of goods, is important to reduce costs and ensure human health. In order to evaluate logistics performances, the World Bank uses the Logistics Performance Index [b-LPI], which reflects the efficiency of customs clearance, the quality of transportation infrastructure, the ease of arranging shipments, the quality of logistics service, the quality of tracking and tracing, and timeliness. However, LPI does not consider records of goods delivery. Therefore, it is important to consider the logistics satisfaction index, which reflects the goods delivery experience on the delivery route.

As shown in Figure I.6, logistics companies, individual vehicle companies and users can trace goods in real time using IoT technology, even if multiple transportation means are used on the delivery route. A smart logistics service, in particular a cold chain service, can be improved by using IoT sensors and actuators (e.g., installed on containers and in warehouses).

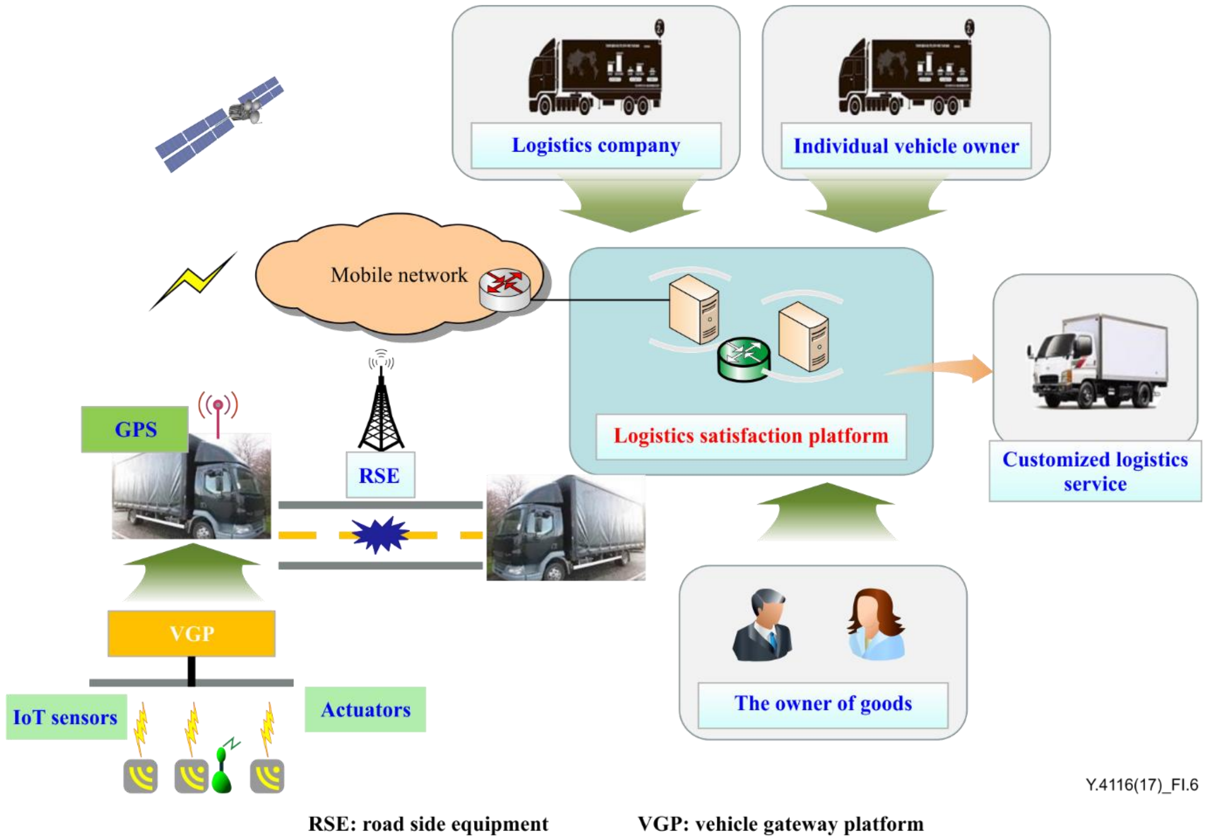

Figure I.6 – The concept of smart logistics service

A freight vehicle may host global positioning system (GPS) receivers and several kinds of IoT sensors, such as those for vibration, temperature and humidity. All IoT sensors are connected to a VGP [b-ITU-T F.749.1] in order to pre-process and deliver sensing data to the logistics satisfaction platform. The logistics satisfaction platform can provide logistics satisfaction indexes to logistics companies as well as to the general public.

Freight can sustain immanent damage during delivery due to various experiences according to delivery route, road surface conditions, delivery delay, etc. Therefore, it is necessary to generate a logistics satisfaction index that reflects the degree of satisfaction with goods during the delivery process. The delivery history data that records the delivery status information, such as delivery route, vehicle temperature and humidity and vibration on the move, are used for evaluation of delivery satisfaction.

The logistics satisfaction platform can evaluate the logistics satisfaction index for individual goods, for delivery vehicles, as well as for logistics companies, using IoT sensing data from vehicles and goods. Therefore, the logistics satisfaction platform can support users of goods for the selection of a customized logistics service.

A logistic satisfaction index can be generated from weighted satisfaction scores that can be calculated from the IoT sensing data during the delivery process.

Figure I.7 shows the concept of satisfaction score generation.

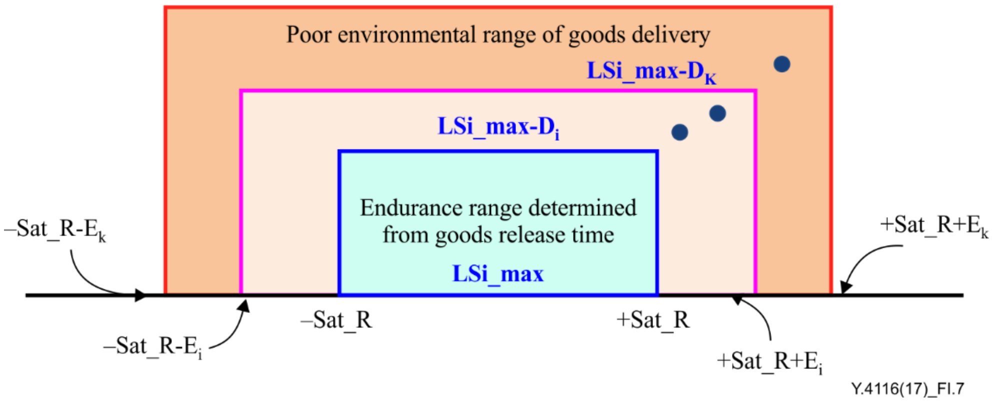

Figure I.7 – The concept of satisfaction score generation

All kinds of goods can endure external environmental parameters, such as vibration and temperature, within a marginal range (-Sat_R ~+Sat_R) that is determined at production time. However, values of external environmental parameters out of the marginal range (-Sat_R-E_k~-Sat_R-E_i~-Sat_R, +Sat_R+E_k~+Sat_R+E_i~+Sat_R) can cause serious damage immediately or afterwards. It is possible to estimate the degree of damage by comparing current environmental sensing data to the endurance range value, i.e., if the value of a current environmental sensing data falls within [{-Sat_R-E_i~-Sat_R},{+Sat_R ~+Sat_R+E_i}], then the satisfaction score in this region can be estimated as LS_i_max-D_i, where D_i are the offset values from LS_i_max in the endurance range.

For the generation of the logistics satisfaction index that reflects the weighted satisfaction score, several kinds of environmental parameters can be used. The following equation provides an example of logistics satisfaction index calculation:

$$LS = \sum_{j=1}^{m} W_j \cdot \frac{\sum_{i=1}^{k}\{LS_{i}\_\max - D_i\} \cdot T_i}{D\_T}$$

LS: logistics satisfaction index;

W_j: weight factor for IoT sensor j;

LS_i_max: maximum value of satisfaction score, which means the best satisfaction status;

D_i : offset value from LS_i_max;

T_i : observation time slot duration for the renewal of satisfaction index;

D_T: total delivery time of goods, that is, total time duration for the generation of satisfaction index.

The IoT sensing data may be made accessible to the public to enable the generation of a logistic satisfaction index by the public.

Also, the possibility of enabling the control by third parties of IoT sensors and actuators can influence the logistic satisfaction index.

Appendix II

The relationship between requirements in clause 7 and use cases in Appendix I

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

Some of the requirements provided in clause 7 are explicitly derived from the use cases of Appendix I, meanwhile other requirements are only related in implicit way to the use cases. Table II.1 shows the relationship between the requirements provided in clause 7 and the use cases described in Appendix I.

Table II.1 – Relationship between requirements and use cases

Requirements		**Use cases (clause)**					**Remark**
Clause	Topic	I.1.1	I.1.2	I.1.3	I.2	I.3	
7.1 Sensor requirements	1) Control					v	
	2) Calibration						Implicit relationship
	3) Operating power	v		v			
	4) Configuration						Implicit relationship
	5) Sensing period			v			
	6) Time stamp by sensor		v				
	7) Sensing capacity			v			
7.2 IoT sensing network requirements	1) Sensor connectivity	v	v			v	
	2) Sensor cooperation	v	v		v		
	3) Connectivity with other networks		v	v		v	
	4) Internet connectivity		v	v		v	
	5) Multicasting service			v			
	6) Sensing network coverage extension			v			
	7) Delay tolerant technologies		v				
7.3 IoT sensing data delivery requirements	1) Data compression		v	v			
	2) Data security						Implicit relationship
	3) Timing information		v				
	4) Data format	v			v	v	
	5) Interconnection using standardized ITS technologies				v		
	6) Interconnection using standardized LTE-R technologies			v			
	7) Interconnection using standardized e-navigation technologies						Implicit relationship

Table II.1 – Relationship between requirements and use cases

Requirements		Use cases (clause)					Remark
7.4 Disaster monitoring requirements	1) Anticipation and detection		v	v			
	2) Hierarchy of decision-making		v	v			
	3) Anticipation accuracy		v	v			
	4) Detection accuracy		v	v			
7.5 Maintenance requirements of transportation infrastructure and vehicles	1) Transportation infrastructure safety		v	v	v		
	2) Safety index		v	v			
	3) Maintenance		v	v			
	4) Transportation infrastructure safety modelling		v				
	5) Warning of vehicle status		v	v	v		
	6) Safety trend forecast		v				
	7) Self check for safety						Implicit relationship
	8) Online self-check						Implicit relationship
	9) Online maintenance						Implicit relationship
7.6 Disaster simulation requirements	1) Simulation based on IoT sensing data		v	v	v		
	2) Accuracy of disaster simulation		v	v	v	v	
	3) Cause of disaster		v		v		
	4) Accident propagation		v		v		
	5) Estimation of affected area of disaster				v		
	6) Disaster estimation model		v				
7.7 Management requirements of transportation safety services	1) Scope of safety management						Implicit relationship
	2) Data resources		v				
	3) Repair history		v	v			
	4) Driver's tiredness		v				
	5) Measurement method of tiredness		v				
7.8 Application service requirements of transportation safety	1) Application service creation by composition of IoT sensing data		v	v	v	v	
	2) Virtual IoT sensors		v				

Table II.1 – Relationship between requirements and use cases

Requirements		Use cases (clause)					Remark
	3) Emergency network facilities		v				
	4) Safety transportation service provisioning			v			
	5) Condition-based maintenance			v			
	6) Logistics satisfaction index					v	
	7) History of delivery					v	

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