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Audiovisual services

Requirements for water quality assessment services using ubiquitous sensor networks (USNs)

Recommendation ITU-T F.747.6

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Recommendation ITU-T F.747.6

Requirements for water quality assessment services using ubiquitous sensor networks (USN)

Summary

To make a safe and ecologically healthy water environment, assessment of changes in water quality and water quality monitoring are required in rivers, lakes and other bodies of water. Recommendation ITU-T F.747.6 describes scenarios for the applications of water quality assessment and the sensor network technology that is the most suitable method to fulfil it.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T F.747.6	2014-10-14	16	11.1002/1000/12226

Keywords

Ubiquitous sensor network (USN), water quality assessment (WQA).

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

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The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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1 Scope

This Recommendation identifies requirements and scenarios for water quality assessment (WQA) services using ubiquitous sensor networks (USNs). The scope of this Recommendation covers the following:

– Overview of WQA;

– WQA scenarios;

– Requirements for WQA services;

– USN capabilities for supporting the requirements of WQA services.

2 References

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

[ITU-T F.744] Recommendation ITU-T F.744 (2009), *Service description and requirements for ubiquitous sensor network middleware*.

[ITU-T Y.2221] Recommendation ITU-T Y.2221 (2010), *Requirements for support of ubiquitous sensor network (USN) applications and services in the NGN environment*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 processed data [ITU-T F.744]: Data that are processed from raw sensed data by the sensor network or USN middleware.

3.1.2 sensed data [ITU-T F.744]: Data sensed by a sensor that is attached to a specific sensor node.

3.1.3 sensor [ITU-T Y.2221]: An electronic device that senses a physical condition or chemical compound and delivers an electronic signal proportional to the observed characteristic.

3.1.4 sensor network [ITU-T Y.2221]: A network comprised of inter-connected sensor nodes exchanging sensed data by wired or wireless communication.

3.1.5 sensor node [ITU-T Y.2221]: A device consisting of sensor(s) and optional actuator(s) with capabilities of sensed data processing and networking.

NOTE– In WQA environment, these sensor nodes have sensing and networking capabilities except sensed data processing.

3.1.6 ubiquitous sensor network (USN) [ITU-T Y.2221]: A conceptual network built over existing physical networks which makes use of sensed data and provides knowledge services to anyone, anywhere and at any time, and where the information is generated by using context awareness.

3.1.7 USN end-user [ITU-T Y.2221]: An entity that uses the sensed data provided by USN applications and services. This end-user may be a system or a human.

NOTE – In WQA environment, a WQA user is a kind of USN end-user. This may be a WQA application or a human.

3.1.8 USN gateway [ITU-T Y.2221]: A node which interconnects sensor networks with other networks.

NOTE – In WQA environment, the USN gateway has the sensed data processing capabilities.

3.1.9 USN middleware [ITU-T Y.2221]: A set of logical functions to support USN applications and services.

NOTE – In WQA environment, a WQA server is a kind of USN middleware. The main functionalities of it are sensor network management and sensor data mining and processing.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 measured data: The sensing data by a sensor that is attached to a specific sensor node.

3.2.2 software sensor: Software that gets the processed and predicted data from measured real-time sensed data.

NOTE – WQA server has the software estimating the processed data (e.g., total nitrogen (TN) and total phosphorus (TP) values) using the water quality parameters (e.g., potential of hydrogen (pH), dissolved oxygen (DO), electrical conductivity (EC)) aggregated from sensors in sensor networks in real-time.

3.2.3 water quality assessment (WQA) node: A device measuring water quality and capable of sensing, processing, networking and optionally actuating.

3.2.4 WQA system: The devices consisting of sensor nodes with sensors, a USN gateway and a WQA server in order to support the water quality assessment.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DO	Dissolved Oxygen
EC	Electrical Conductivity
IP	Internet Protocol
IPv4	Internet Protocol version four
IPv6	Internet Protocol version six
ORP	Oxidation-Reduction Potential
pH	Potential of Hydrogen
TN	Total Nitrogen
TP	Total Phosphorus
USN	Ubiquitous Sensor Network
WQA	Water Quality Assessment

ZIP Zone Improvement Plan

5 Conventions

None.

6 Overview of water quality assessment

The water quality assessment (WQA) monitors dispersion of water pollution, tracking of a water pollutant source and predicts water quality change using the values measured from the measurement devices covering a specified area. It plays an important role to improve water quality through its real-time management.

WQA is divided into water quality management for wide areas and for middle and small-sized areas such as rivers or lakes. In the former case, it is easy to monitor a large water pollutant accident, while the latter is used to prevent the spread of water pollution and to monitor water pollution before the water pollutant, actually generated at middle and small-sized rivers, is diluted.

Applications for the WQA include the smart farm (for example, the horticultural and livestock industries) and smart leisure (for example, fishing where the angler is interested in information related to water quality, or the different opinions about a water pollutant source among local communities). These applications use sensor network technologies to assess water quality. The WQA nodes with water quality sensors deliver sensing data in real-time to a WQA server via wireless or mobile networks. The sensed data are used to monitor the water quality and track the water pollutant source in real-time. Furthermore, the large-scale deployment of a sensor network enhances the density of the WQA node thus realizing reliable water quality assessment. Besides, unmanned long-term operation of the WQA system is possible through network management technologies together with low power consumption and automated control of sensors.

Figure 1 shows the overall conceptual diagram for the WQA. The device with the water quality sensor, flow sensor, water level sensor, etc., by the rivers and lakes periodically measures the value of the water quality parameters (e.g., potential of hydrogen (pH), dissolved oxygen (DO)), the flow velocity, the water level, etc. The sensed data are delivered to the WQA server located in infrastructure network. WQA server estimates the WQA information based on the sensed data. WQA server provides the information to WQA users in real-time.

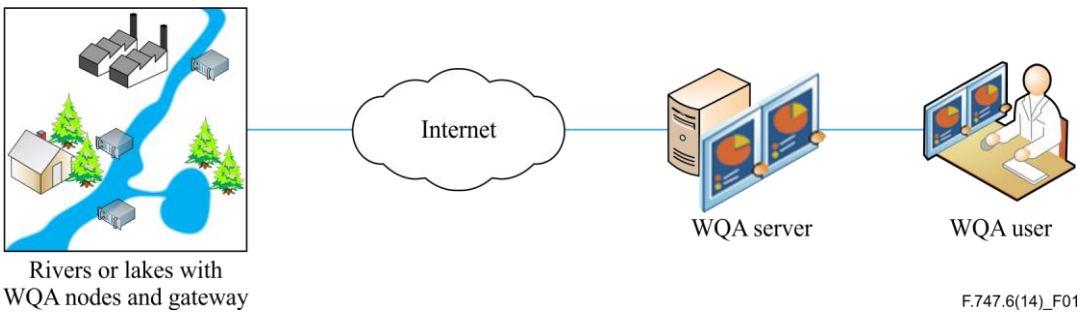

Figure 1 – Overall conceptual diagram for WQA

7 Scenarios for WQA services

The scenarios for the WQA include the following entities: the WQA nodes, server and users and are done through the interaction among them.

7.1 Scenario I: Real-time water quality data aggregation

Scenario I describes procedures where the measured data for the WQA are delivered periodically to the WQA server and, subsequently, the water quality information is provided to users in real-time.

1) The WQA server initially sets the data-sensing period of the WQA node.

2) The WQA nodes obtain the measured data periodically from the rivers, lakes, etc.

3) The data measured by the WQA nodes and gateway are delivered to the WQA server.

4) Steps 2 and 3 above are repeated after waiting for the data-sensing period. The WQA server estimates the water quality to provide the distribution of each water parameter from the delivered measured data.

NOTE – The procedures from step 1 to step 3 are obtaining periodic measured data. In the scenario II and III, below, the same procedures are used.

5) The WQA server derives the water quality distribution map of each water quality item by applying the WQA model.

6) The WQA server provides the information on the water quality distribution to the WQA users.

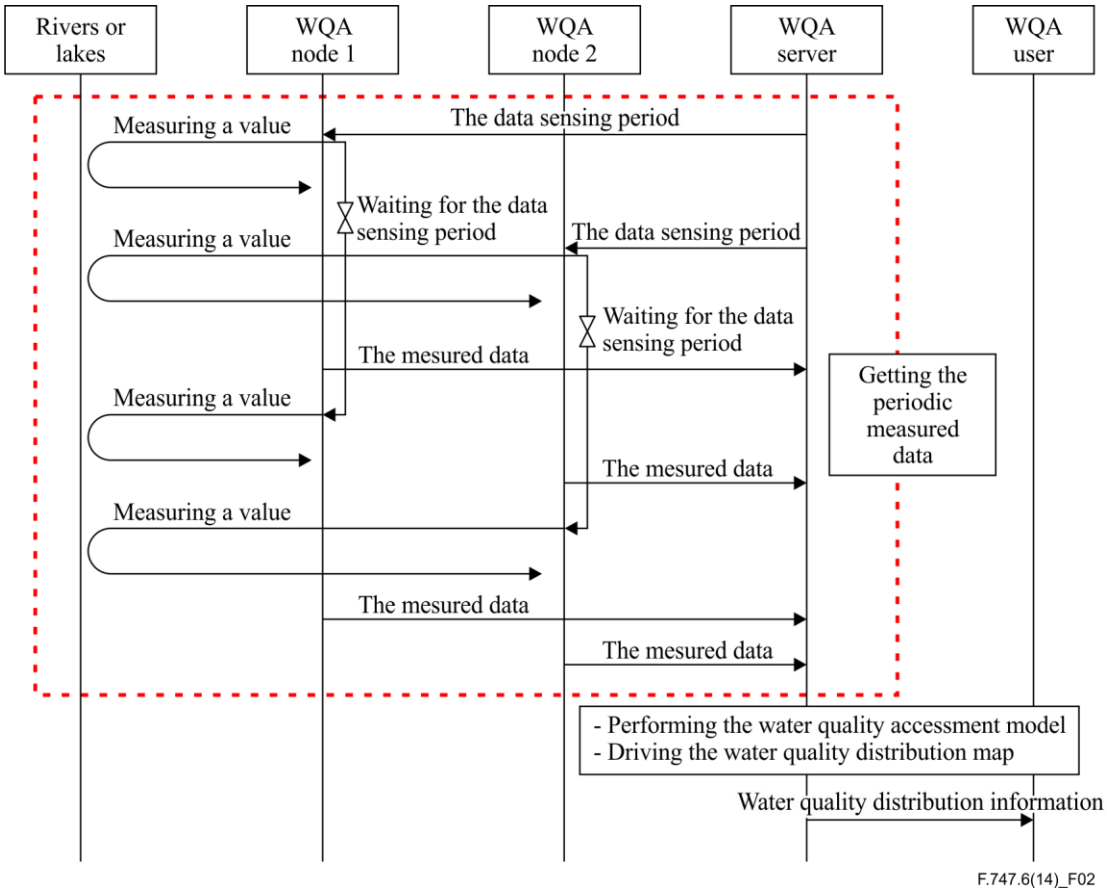

Figure 2 – Real-time water quality data aggregation

7.2 Scenario II: Automatic WQA node control

The WQA server monitors the water quality parameters measured from the WQA nodes and then filters any faults to improve the accuracy of the WQA. It also distinguishes sensing faults from the aggregated sensed data. For example, the WQA server can operate the sensor wiper of WQA node to prevent bio-fouling.

Scenario II describes procedures for long-term unmanned operation of the WQA where the WQA server recognizes the changes, or faults, of sensor values and automatically controls the data sensing period and the operation of the sensor wiper.

1) When the WQA server analyses the measured data, and if a change to the data sensing period is required, it requests the WQA nodes to change the period.

2) The WQA nodes obtain sensing data with the new data sensing period from the rivers, lakes, etc. The sensed data by the WQA node are delivered to the WQA server.

NOTE – The same procedure for obtaining the periodic measured data is used as in Figure 2.

3) The WQA server examines the changes or faults of sensor values.

4) When the WQA server recognizes changes, or faults, of sensor values, it automatically controls the data sensing period and the operation of the sensor wiper.

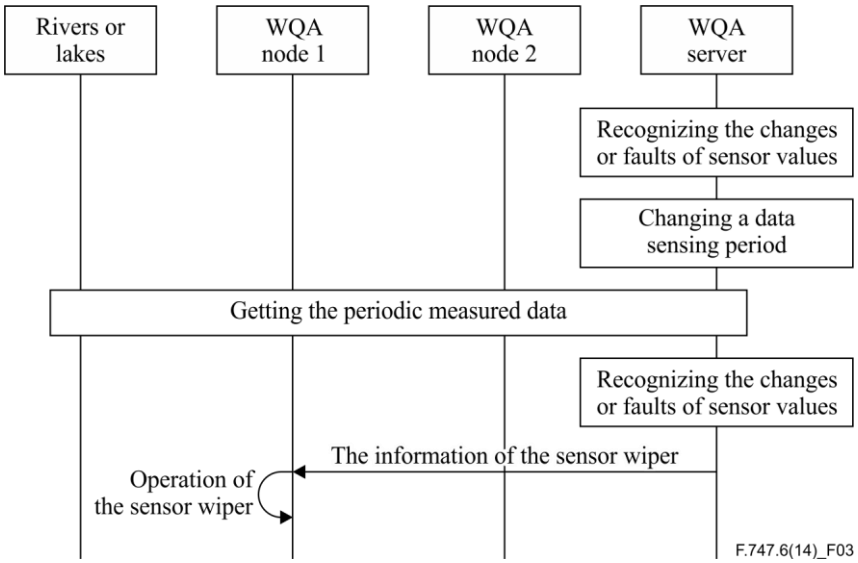

Figure 3 – Automatic WQA node control

7.3 Scenario III: WQA node surveillance and logging

Scenario III describes the procedure where the WQA server observes the WQA nodes and then detects, separates and diagnoses faults of the devices. If the communication between the WQA server and the WQA nodes is interrupted, the WQA node must log the measured data until it returns to a normal communication state. Thus, fault monitoring among the WQA nodes is important.

1) The WQA nodes obtain the measured data in every period from the rivers, lakes, etc. The measured data are delivered to the WQA server.

NOTE – The same as the procedure for obtaining the periodic measured data is used as in Figure 2.

2) The WQA server periodically performs surveillance of the WQA nodes.

3) The device receiving a surveillance request delivers the result to the WQA server. On the other hand, when a node detects a fault, it is delivered to the server.

4) When the communication between the WQA server and the WQA nodes is interrupted, the WQA node logs the measured data.

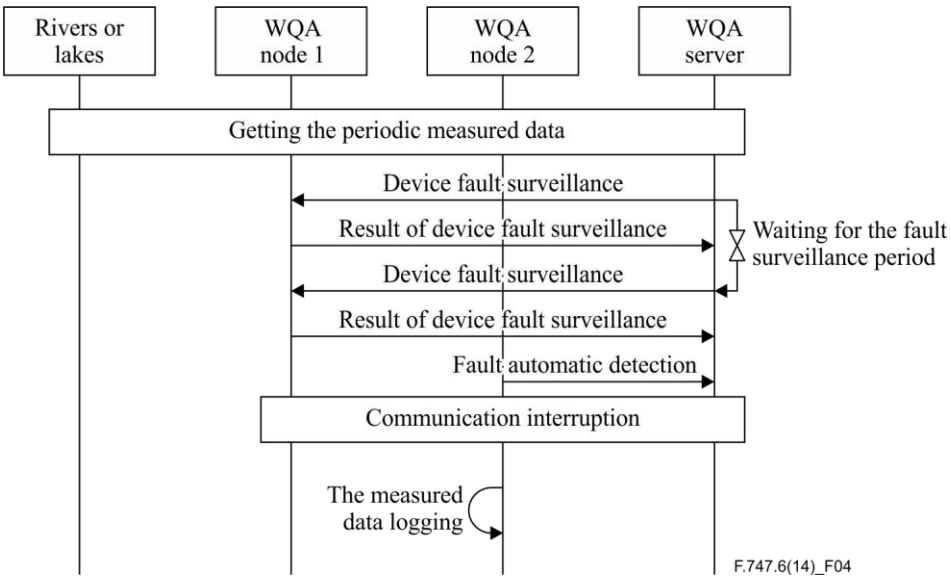

Figure 4 – WQA node surveillance and logging

7.4 Scenario IV: Water quality prediction through software sensors

Scenario IV describes procedures that predict values of water quality parameters through software sensors. In general, WQA nodes measure the values of water quality parameters (e.g., pH, DO, electrical conductivity (EC)) in real-time using water quality sensors. However, total nitrogen (TN) and total phosphorus (TP) values, which are important criterion parameters for judgment of water pollution, are not measured via the WQA nodes in real-time due to its measurement method. Hence, the values of these parameters are predicted through the software sensor in real-time. TN and TP values obtained from the software sensor are offered as the input values for the analysis of water quality distribution, tracking of a water pollutant source and the prediction of the water quality change.

1) The WQA nodes obtain the measured data in every period from the rivers, lakes, etc.

2) The measured data are delivered to the WQA server.

3) The WQA server updates the estimation function of the software sensor with the measured data. Here, initial TN and TP values are time series data measured in advance (measured by getting the water samples and testing its quality at the laboratory or by underwater pumps at the monitoring stations that are built beside rivers). The rest of the values (e.g., pH, DO, EC) are time series data measured in real-time from WQA nodes.

4) The WQA server performs the estimation function of the software sensor. The software sensor, based on the values measured from WQA nodes, estimates TN and TP values in real-time.

5) The WQA server delivers the values from the software sensor module to the WQA module in order to analyse the water quality distribution, the water quality prediction and the total amount of water pollution.

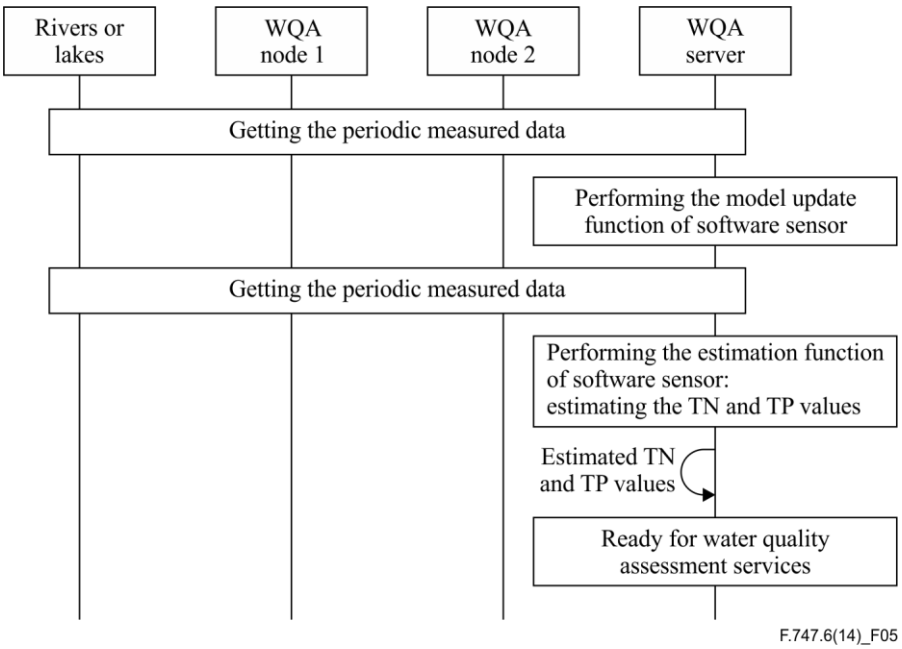

Figure 5 – Water quality prediction through software sensors

8 Requirements of WQA services

8.1 Reliable data transfer

Because the WQA services such as dispersion of the water pollution, tracking of the water pollutant source and the prediction of the water quality change are using the values measured from the WQA nodes, reliable data transfer without any data loss from WQA node to WQA server is required.

8.2 Real-time water quality information transfer

The WQA information including sensing data, aggregated data, control data, the results of water quality analysis, etc., is required to deliver to the WQA server in real-time. It allows the public authorities to monitor the information and to handle the water pollutant accident in real-time. It also satisfies the user's desires to receive the information in prompt.

8.3 Bidirectional communication

While the WQA node offers information to the WQA server periodically, the WQA server delivers control information to the WQA node. Thus, the bidirectional communication is recommended to support the smooth operation of the WQA system.

8.4 Security

Security services are required, for example, to protect the integrity, delivery and confidentiality of water quality data, in order to provide accurate WQA.

8.5 Water assessment modelling

Precise water pollution dispersion, prediction and water pollutant source tracking by using the measured data are required. To achieve this and to provide WQA services accurate modelling of WQA is essential.

9 USN-based WQA services

Ubiquitous sensor network (USN)-based WQA services are provided by the analysis of the data measured from sensors within the sensor network. A WQA server, using sensing data, assesses changes in water quality and performs water quality monitoring through the aggregated sensing data in real-time.

The sensor network consists of WQA nodes with sensors and a gateway. Sensors measure the value of the water quality parameters (e.g., pH, DO, EC, oxidation-reduction potential (ORP)), the flow velocity, the water level, etc. The WQA nodes aggregate the sensing data from various sensors and send it to the USN gateway. The USN gateway also sends the aggregated data to the WQA server where the WQA is performed. Therefore, the WQA system provides following WQA services.

9.1 Water quality distribution service

The water quality distribution service provides water quality distribution map of rivers, lakes, ponds, etc. in real-time where WQA nodes are installed. For the service, the WQA server calculates estimated values of TN and TP in real-time using a software sensor. The WQA server offers water quality distribution in real-time for water temperature, turbidity, pH, TN or TP of middle and small-sized rivers.

9.2 Water quality prediction service

The water quality prediction service provides water quality prediction values of rivers, lakes, ponds, etc. in real-time where WQA nodes are installed. For the service, the WQA server calculates estimated values of TN and TP in real-time using a software sensor. The WQA server offers prediction of water quality change in real-time for TN or TP of medium and small-sized rivers.

9.3 Service for total amount of polluted water

The total amount of polluted water service provides the total amount of the polluted water of rivers, lakes, ponds, etc. in real-time where WQA nodes are installed. For the service, the WQA server calculates estimated values of TN and TP in real-time using software sensor. The WQA server offers the total amount of water pollution in real-time for flow velocity, water level, TN or TP of medium and small-sized rivers.

10 USN capabilities for WQA services

10.1 Reliable communication link in sensor networks

The sensor networks are deployed in a large area in an outdoor water environment. Even if they have poor radio environment, reliable delivery of sensing data is required. That is, the WQA system offers an optimal communication link considering its operation and the characteristics of the sensing information. It also has to guarantee high end-to-end success rate of the data transmission.

10.2 Transmission delay guarantee to the WQA server

The measured data from sensors is delivered in real-time to the WQA server. For that, the transmission delay (for example, data processing time and transmission time in the sensor networks) is guaranteed. The transmission delay over the Internet is also guaranteed.

10.3 Low power consumption in sensor networks

The sensor network needs to provide uninterruptible power for long-term unmanned operation in a broad area. It must have sensors or sensor nodes that consume low electric power. It also has to use low power mechanisms or its own power supply.

10.4 Bidirectional communication between WQA nodes and servers

In general, the data in sensor networks are transferred in an upward direction. However, the control data, which are transferred in a downward direction, are needed to control the sensors and USN gateways for the unmanned long-term operation in WQA system. For example, Internet protocol (IP) infrastructure is a good candidate to support the bidirectional communication.

10.5 Multi-hop data transfer in sensor networks

The sensor network is constructed with an almost linear topology and so the proper multi-hop networking protocol must be considered. WQA nodes must be able to deliver the measured data to the USN gateway through multi-hop paths.

10.6 IP infrastructure compatibility

For the interworking between WQA nodes and WQA servers or between WQA servers and users, IP based networking is considered with the support of Internet protocol version four/Internet protocol version six (IPv4/IPv6) translation.

Along with IP networking, the network management protocol is considered to monitor and operate the WQA nodes in real-time.

10.7 Long distance transmission support in sensor networks

A sensor network may require long distance data transmission (for example, several kilometres) between WQA nodes and USN gateways. Proper communication distance in large area (for example, dozens of kilometres) outside must be guaranteed.

10.8 Security services

The security services are required to protect the delivery of water quality information; to protect data confidentiality and integrity among WQA nodes; to provide authentication between WQA nodes and USN gateways; to provide data confidentiality between the USN gateway and WQA server; and to preform authorization, verification, etc.

10.9 Data logging

The gateway keeps a record of the measured data to prevent data loss due to communication interruptions between the USN gateway and WQA server, server faults, the flooding of WQA nodes, etc.

10.10 Maintainability of sensor networks

The network components in sensor network must be observed and faults must be detected automatically during unmanned long-term operation. Furthermore, the current network status can be optionally reported to the WQA server through the USN gateway. For the prevention of bio-fouling, the sensor control, including changing the data sensing period and operation of the sensor wiper, may be optionally controlled automatically.

10.11 Naming and addressing in sensor networks

The WQA system has two key features: real-time support and direct control of sensors. To support these features, each WQA node with sensors is required to be uniquely distinguished by the naming and addressing method. Here, the naming is recommended to have the relation to river name, zone improvement plan (ZIP) code and others.

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