International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

F.747.2
(06/2012)

SERIES F: NON-TELEPHONE TELECOMMUNICATION SERVICES

Audiovisual services

Deployment guidelines for ubiquitous sensor network applications and services for mitigating climate change

Recommendation ITU-T F.747.2

ITU-T F-SERIES RECOMMENDATIONS

NON-TELEPHONE TELECOMMUNICATION SERVICES

TELEGRAPH SERVICE	
Operating methods for the international public telegram service	F.1–F.19
The gentex network	F.20–F.29
Message switching	F.30–F.39
The international telemessage service	F.40–F.58
The international telex service	F.59–F.89
Statistics and publications on international telegraph services	F.90–F.99
Scheduled and leased communication services	F.100–F.104
Phototelegraph service	F.105–F.109
MOBILE SERVICE	
Mobile services and multidestination satellite services	F.110–F.159
TELEMATIC SERVICES	
Public facsimile service	F.160–F.199
Teletex service	F.200–F.299
Videotex service	F.300–F.349
General provisions for telematic services	F.350–F.399
MESSAGE HANDLING SERVICES	F.400–F.499
DIRECTORY SERVICES	F.500–F.549
DOCUMENT COMMUNICATION	
Document communication	F.550–F.579
Programming communication interfaces	F.580–F.599
DATA TRANSMISSION SERVICES	F.600–F.699
AUDIOVISUAL SERVICES	**F.700–F.799**
ISDN SERVICES	F.800–F.849
UNIVERSAL PERSONAL TELECOMMUNICATION	F.850–F.899
HUMAN FACTORS	F.900–F.999

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

Recommendation ITU-T F.747.2

Deployment guidelines for ubiquitous sensor network applications and services for mitigating climate change

Summary

Recommendation ITU-T F.747.2 provides deployment guidelines for ubiquitous sensor network (USN) applications and services for mitigating climate change.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T F.747.2	2012-06-29	16

Keywords

CC, climate change, GHG, greenhouse gas, USN, ubiquitous sensor network.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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.

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

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.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

Table of Contents

Recommendation ITU-T F.747.2

Deployment guidelines for ubiquitous sensor network applications and services for mitigating climate change

1 Scope

This Recommendation provides deployment guidelines for ubiquitous sensor network (USN) applications and services for mitigating climate change. The scope of this Recommendation includes:

– an overview of climate change monitoring;

– analysis of environmental impact by USN applications and services; and

– the requirements for deployment of USN applications and services for mitigating climate change.

Monitoring climate change covers monitoring the status of greenhouse gas (GHG) emissions, as well as monitoring climate change by tracing temporal changes of GHG emissions.

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.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 climate change [b-IPCC]: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

3.1.2 greenhouse gas [b-ISO 14064-1]: Gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds.

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 interconnected 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.

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

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

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

API	Application Program Interface
CPU	Central Processing Unit
GAW	Global Atmosphere Watch
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
RX	Receiver
TX	Transmitter
UNFCCC	United Nations Framework Convention on Climate Change
USN	Ubiquitous Sensor Network

5 Conventions

None.

6 Overview of climate change monitoring

6.1 Global greenhouse gas monitoring network

Monitoring greenhouse gas (GHG) emissions as well as climate change requires that GHG sensors, sensor nodes and sensor networks are installed nationally and/or globally. A nationwide GHG monitoring network may interwork with a global GHG monitoring network, for example, the one illustrated in Figure 1, which is maintained by the Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO) [b-GAW programme].

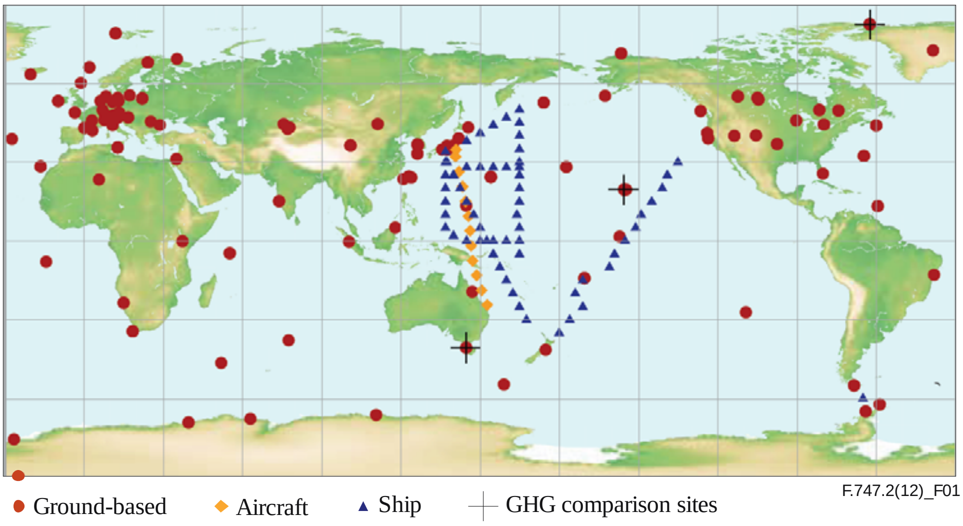

Figure 1 – The WMO-GAW global network for GHG

6.2 Local GHG monitoring network

[b-IPCC Guidelines] defines three tiers for estimating GHG emissions from fossil fuel combustion:

– The tier 1 method is fuel-based, since emissions from all sources of combustion can be estimated on the basis of the quantities of fuel combusted (usually from national energy statistics) and average emission factors. Tier 1 emission factors are available for all relevant direct greenhouse gases.

– The tier 2 method is estimated from similar fuel statistics as used in tier 1, but country-specific emission factors are used in place of the tier 1 defaults. This is because different specific fuels, combustion technologies or even individual plants may produce different country-specific emission factors.

– The tier 3 method uses either detailed emission models or measurements and data at an individual plant level where appropriate. Properly applied, these models and measurements should provide better estimates, primarily for non-CO2 greenhouse gases, though at the cost of more detailed information and effort.

The tier 3 method allows an enterprise to measure real GHG emissions to avoid overestimation that may happen due to the conservativeness principle. In the latter, conservative assumptions, values and procedures are used when data and assumptions are uncertain and the cost of measures to reduce uncertainty is not worth the increase in accuracy. Conservative accounting results for GHG emissions are more likely to be overestimated than underestimated.

Enterprises may install a local GHG monitoring network at their plant level.

7 Analysis of environmental impact by USN applications and services

7.1 Deployment elements of USN

[ITU-T Y.2221] defines USN as a conceptual network and an information infrastructure that delivers sensed information and knowledge services to anyone, anywhere and at any time. In USNs, information and knowledge are developed by using context-aware techniques.

USN applications and services are established by integration of sensor network services into a network infrastructure. They can be applied to everyday life in an invisible way as everything is virtually linked by pervasive networking between users (including machine and human) and sensor nodes, and relayed through intermediate networking entities such as application servers, middleware entities, access network entities, and USN gateways. Integration of the hardware, software, USN applications and USN services can be used in many civilian application areas such as industrial automation, home automation, agricultural monitoring, healthcare, environment, pollution and disaster surveillance, and security.

Figure 2 shows elements of deploying USN applications and services to mitigate climate change. They may cause both positive and negative impacts on the environment.

<table>
<tr><td colspan="4">USN applications and services</td></tr>
<tr><td colspan="4">Backbone network</td></tr>
<tr><td colspan="4">Sensor network (wired, wireless)</td></tr>
<tr><td colspan="2">Gateway</td><td colspan="2">Sensor node</td></tr>
<tr><td>H/W</td><td>S/W</td><td>H/W</td><td>S/W</td></tr>
</table>

Figure 2 – Deployment elements of USN applications and services

7.2 Positive environmental impacts

USN is a key technology to mitigate climate change by monitoring diverse environmental data and enabling energy consuming sources to be controlled according to the environmental data.

Sensor nodes can measure and deliver different types of environmental data, such as, pressure, humidity, temperature, light, chemicals, strain and tilt, speed and acceleration, magnetic fields, vibrations, motion, metal detection and sound.

The sensing parameters are used to trace climate change and to understand climate phenomena. The issues are how to deliver the sensed data and how to manage, present and exploit the data to derive value-added information for countering climate change. This clause briefly introduces examples of how USNs are applied to mitigate climate change.

7.2.1 Direct climate change monitoring

USN applications and services provide direct monitoring for the acquisition of climate data. For example, marine environment monitoring and glacier status monitoring help trace continuous environmental changes.

In order to help counter climate change, it is important to monitor the climate to verify if changes to the environment are caused by human influence or natural phenomena. The use of sensor networks to monitor the climate has been researched for decades; this has allowed the development of viable technology and techniques for monitoring climate change. It has been proved with many experiments, that USN-based monitoring systems give valuable data.

Marine environment monitoring shown in Figure 3 is an example of direct environment monitoring. The data of the sensor nodes used to monitor the real-time status of the marine and glacier environment are transmitted to the local monitoring and management system.

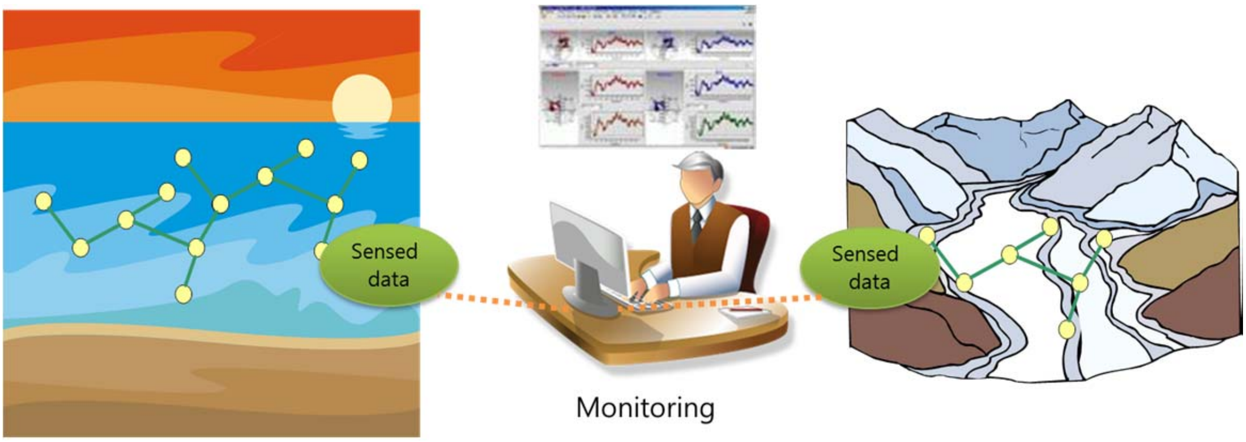

Figure 3 – Example of marine and glacier environment monitoring

Upper air current and atmospheric state monitoring is presented as another direct climate monitoring example, as shown in Figure 4. It includes slightly different features than the general area of climate monitoring. Altitude changes, temperature, humidity and atmospheric flow are the key information for understanding climate change in a certain region.

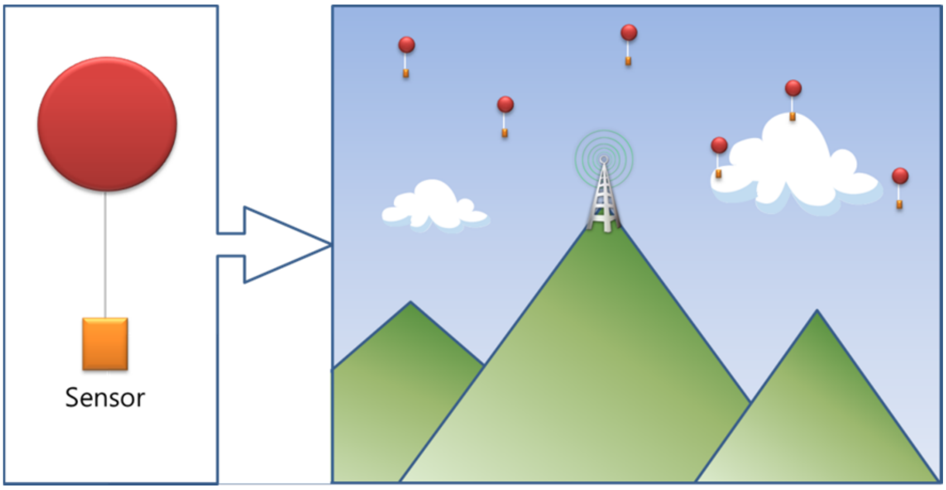

Figure 4 – Upper air current and upper atmosphere state monitoring example

7.2.2 Monitoring and control of GHG emissions

USN applications can be developed to automatically monitor and limit power consumption levels. Various USN applications have the ability to monitor electric power consumption and air pollution to alert users when their systems exceed established thresholds.

A good example of this category of USN applications is a management system of various components in urban infrastructure, such as roads, sewerage, water and gas lines. When USN systems sense a defect, the systems will activate the corresponding maintenance systems to correct the malfunction. For example, a road management system captures road conditions and provides this information to drivers with additional weather information. In addition, USN applications can help reduce GHG emissions caused by stop-and-go traffic through rerouting traffic to less congested routes.

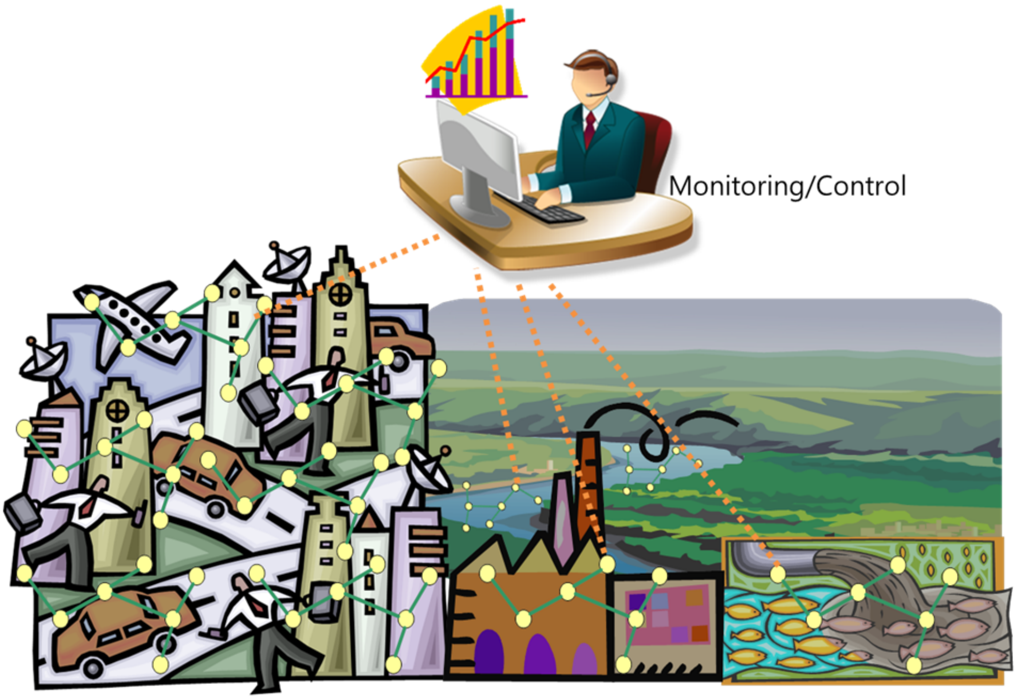

Figure 5 – Management of city facilities example

Another example of monitoring energy and GHG emission is home and commercial building automation. Light bulbs can automatically control the appropriate brightness based on information from motion sensors and ambient light. Home appliances and other electronic gadgets can enter energy-saving modes when not in use. Controlling power consumption levels and GHG emissions of commercial buildings is more complex than controlling the consumption and emissions levels of single-family homes. However, the same type of automation equipment or similar system concepts can be used in commercial buildings. Home and building monitoring servers are able to show the monitored power consumption levels to allow owners to adjust usage levels appropriately. These monitoring and control systems are known to reduce GHG emissions on average by about 10%.

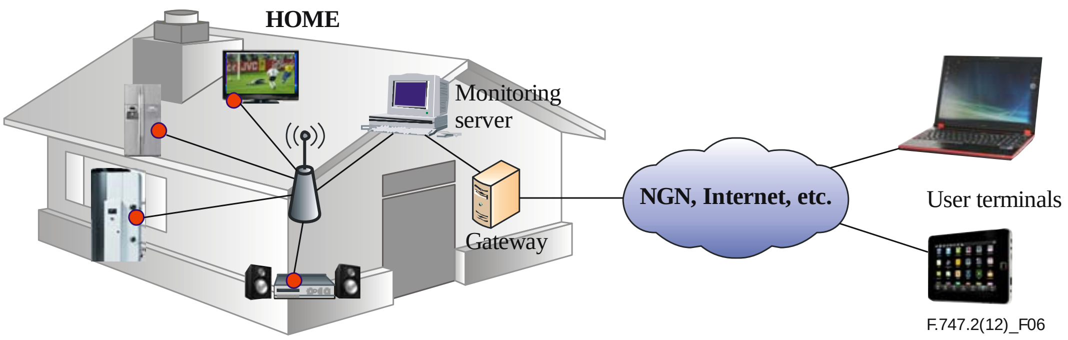

Figure 6 – Home GHG monitoring example

7.2.3 Indirect monitoring to learn climate features

There are many USN applications that allow indirect monitoring for the acquisition of climate data. This type of USN application is essential in allowing researchers to analyse and understand climate change. Understanding climate change is the first step in developing strategies to deal with impending crises that could threaten global supplies for drinking water, sanitation and irrigation.

USN applications can be extensively deployed to monitor any environmental changes and help understand the cause of the change. The results of the collected data can be used to predict future changes.

A hydro watch USN application builds wireless sensor networks to more closely examine the water cycle and can be used to understand climate phenomena. Sensor nodes may be installed in greenhouses and in open fields, and a sensor network application monitors the agricultural environment and learns about the plants' habitat, in order to help manage optimal plant growing conditions.

7.3 Negative environmental impacts

As global awareness on climate change rises in the ICT sector, there is also increased awareness of the environmental impact of electric and electronic products, the restriction on the use of hazardous substances and the use of eco-designs. Furthermore, GHG emission by-products are generated in the life cycle of all raw materials including material processing, manufacturing, distribution, use, repair and maintenance, and the disposal or recycling of products. Although USNs are not an exception in this aspect, they can be used in many areas and cause a positive net environmental impact.

7.3.1 Use of hazardous materials

The elements of USN contain physical equipment such as gateways, sensor nodes, sensors and batteries. This includes small sensor nodes mostly powered by batteries. Batteries contain heavy metals such as mercury, lead, cadmium and nickel, which can contaminate the environment if batteries are improperly disposed. If the used sensor node cannot be collected, the electronics waste generated from USN physical equipment and certain metals can release hazardous elements in the ash produced by the combustion process. Therefore, the recovery from environmental pollution by electronic waste causes further GHG emission.

7.3.2 Indirect GHG emissions

USN applications and services will cause an environmental load in each product life cycle phase. However, most of the environmental load is caused by using electric power in the use phase. Consuming electric power causes indirect GHG emission from power plants (e.g., thermoelectric power plants, etc.) where the GHG were produced during electric power generation.

8 Requirements for deployment of USN applications and services for mitigating climate change

Even though USN applications and services have a greater positive impact on mitigating climate change in various areas, they are not free from GHG emission as described in clauses 7.2 and 7.3. Therefore, it is important to deploy and utilize USN applications and services in an environmentally-friendly manner. In addition, eco-design and eco-operations must be considered in sensor network gateways and other dedicated servers, as well as sensor nodes.

8.1 Environmentally friendly resources

Sensor nodes are designed and manufactured in small sizes with small memory and low processing power, and run on very limited power supplied by non-rechargeable batteries. This basic design principle of sensor nodes with small sizes and low processing power makes USN applications and services a good solution to pursue low carbon emissions. However, there are many areas still to be considered, such as the materials of the elements, batteries, resource recycling, etc. In particular, the use of solar batteries or other alternative environment-friendly energy sources must be taken into account.

8.1.1 Materials for elements

In the case of using sensors to monitor the weather or collect environmental information, the environmental load due to sensors has to be minimized. Generally, products emit GHG during all of their life cycles, from raw material acquisition to the final disposal of the products. In addition, environmental load is also caused by the use of harmful raw materials. Therefore, if decommissioned sensor nodes can be collected, GHG emissions can be reduced by reusing or recycling them. In case decommissioned sensor nodes cannot be collected, the environmental load can be minimized if the sensor node is made of environment-friendly materials. Thus, the following should be considered for USN elements:

– using environment-friendly materials for sensor node and related equipment;

– using recyclable materials for sensor node and/or reusable sensor node;

– avoiding hazardous materials for sensor node and related equipment;

– managing the location information of sensor nodes for collection.

8.1.2 Batteries

Batteries and energy resources containing hazardous materials have a serious impact not only on GHG emissions but also on the environment. The fact that sensor nodes are often used in the mobile situation and require frequent battery maintenance, they can cause an unnecessarily large GHG footprint. On the other hand, energy saving and harvesting using environment-friendly resources (such as solar energy) can minimize the GHG footprint of sensor nodes. Thus, one should consider the following concerning the use of batteries in sensor nodes:

– using environment-friendly or rechargeable batteries;

– using high capacity batteries for the reduction of electronic waste;

– using environment-friendly energy sources (e.g., solar energy, electromagnetic energy, thermal energy).

8.2 Energy efficiency

Figure 7 illustrates the typical energy consumption of a sensor node. The total energy used in the sensor node is calculated as the sum of the energy used in each part of the sensor node. Particularly, the energy is most used for communications. Energy used in calculation and other tasks is relatively small. Figure 7 shows that the overall energy efficiency can be drastically increased by designing for low energy consumption communications and by using an energy-efficient operation of communications.

This clause classifies three categories of energy efficiency which should be considered in not only wireless sensor networks but also wired sensor networks.

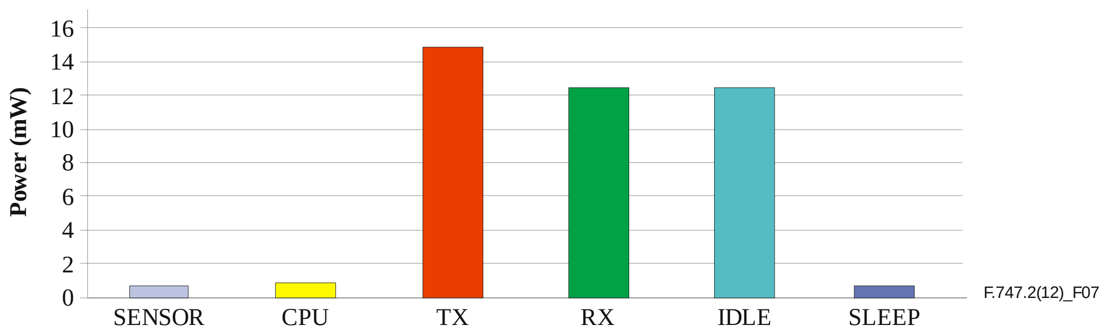

Figure 7 – Energy consumption for a typical sensor reported in [b-IEEE VTC]

8.2.1 Energy efficient hardware setting

Sensor nodes rely mainly on small batteries for their lifetime, all programs must be implemented with a small code size and require minimal power consumption. Power-aware networking and data delivery are a pivotal feature for the longevity of nodes and their batteries, and to reduce electronic waste. Thus, the following considerations apply to hardware settings for sensor nodes:

– To deploy a sufficient number of devices: density and network radius vary amongst different applications and services. Redundant communication may cause the unnecessary consumption of power, and too scarce deployment may cause an unnecessary increase in retransmissions, thus wasting energy.
– To consider radio power and interference, especially obstacles to radio transmissions in an indoor environment.

8.2.2 Energy efficient protocols

For efficient energy consumption, diverse modes (e.g., sleep, idle and hibernate operation modes) and their efficient operation must be supported. The sampling rate for gathering data may be different for each application and service. Thus, protocols for sensor nodes and sensor networks need to consider the following:

– support of diverse modes (e.g., sleep, idle, and hibernate operation modes);
– implementation codes should be as small as possible;
– minimize sensing, calculation and communication;
– equally consume energy on sensor nodes at the same networks;
– support self-recovery, tolerant networks and remote management (movement prevention for frequent maintenance).

8.2.3 Energy efficient applications and services

USN applications and services for different purposes are being developed such as climate monitoring systems and home or building automation systems. Existing USN applications and services create other new services by convergence and they can be used to mitigate climate change. Thus, applications and services for USN have the following considerations:

– to reduce the operations of sensor node;
– to perform the processing load on server;
– to reuse already deployed USN applications and services (when applicable);
– to develop USN applications and services for multi-use of the sensed data (e.g., database schema, API, USN middleware);
– to include the sensor network management function in USN applications and services for automatic checking and the remote reset of USN element malfunction;
– to analyse the application of USN applications and services for energy saving (e.g., control of electric lighting, ventilation, air conditioning and heating).

NOTE – Energy saving should be carefully considered when USN applications and services apply to the facilities which directly relate to people's lives (e.g., surgery room, intensive care unit, emergency room, incubator).

8.3 Operation conditions of GHG sensors

A national GHG monitoring sensor network may have to be established by national regulations, domestic standards, or international standards. They may contain a set of specifications prescribing conditions for geographic locations, target GHGs, sensing frequencies, standard reference GHGs, calculation formulas, meter configurations, device positions, etc. Practitioners should check them before deploying USN applications and services.

Bibliography

[b-GAW programme] WMO Global Atmosphere Watch home page <http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html>

[b-IEEE VTC] Ding, M., Cheng, X., and Xue, G. (2003), *Aggregation tree construction in sensor networks*, Vehicular Technology Conference, 2003. Vol.4, No., pp. 2168- 2172, IEEE.

[b-ISO 14064-1] ISO 14064-1 (2006), Greenhouse gases – Part 1: *Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*.

[b-IPCC] IPCC Working Group 1 Report (2007), *Glossary of Terms used in the IPCC Fourth Assessment Report*.

[b-IPCC Guidelines] IPCC Guidelines for National Greenhouse Gas Inventories (2006).

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	**Non-telephone telecommunication services**
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Terminals and subjective and objective assessment methods
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2013