# Ubiquitous Sensor Networks (USN)

**ITU-T Technology Watch Briefing Report Series, No. 4** (February 2008)

## 1. UBIQUITY ANYWHERE

When you enter a modern office building, such as ITU-T's office in Geneva, it is quite common for the glass doors to open automatically and for lights to come on as you enter a darkened room. This "magic" is achieved by motion sensors. When entering a building of the future, you might be welcomed by name with a personal greeting and given security access suitable to your status (e.g., employee, delegate, newcomer). To do this without human intervention would require not only intelligent sensors but also perhaps ID tags, readers and interaction with one or more databases containing your profile.

**ITU Technology Watch Briefing Reports** are intended to evaluate the potential of emerging technologies, in a manner that is accessible to non-experts, with a view to:

- Identifying candidate technologies for standardization work within ITU.
- Assessing their implications for ITU Membership, especially developing countries.

Other reports in the series include:
#1 Intelligent Transport System and CALM
#2 Telepresence: High-performance video-conferencing
#3 ICTs and climate change
*See: www.itu.int/ITU-T/techwatch/reports.html*

These three elements—sensors, tags and communication/processing capacity—together make up a future network vision identified by a number of different names. Some use the terms "invisible", "pervasive" or "ubiquitous" computing[1], while others prefer to refer to "ambient intelligence"[2] or to describe a future "Internet of Things".[3] In this report, the fourth in the series of ITU-T Technology Watch Briefing Reports, the term "Ubiquitous Sensor Networks" (USN) is used to describe a network of intelligent sensors that could, one day, become ubiquitous. The technology has enormous potential as it could facilitate new applications and services in a wide range of fields — from ensuring security and environmental monitoring, to promoting personal productivity and enhancing national competitiveness (see Figure 1). But USN will also require huge investments and a large degree of customization. As such, it presents a standardization challenge with an unusually high degree of complexity.

## 2. ANYWHERE, ANYTIME, BY ANYONE AND ANYTHING

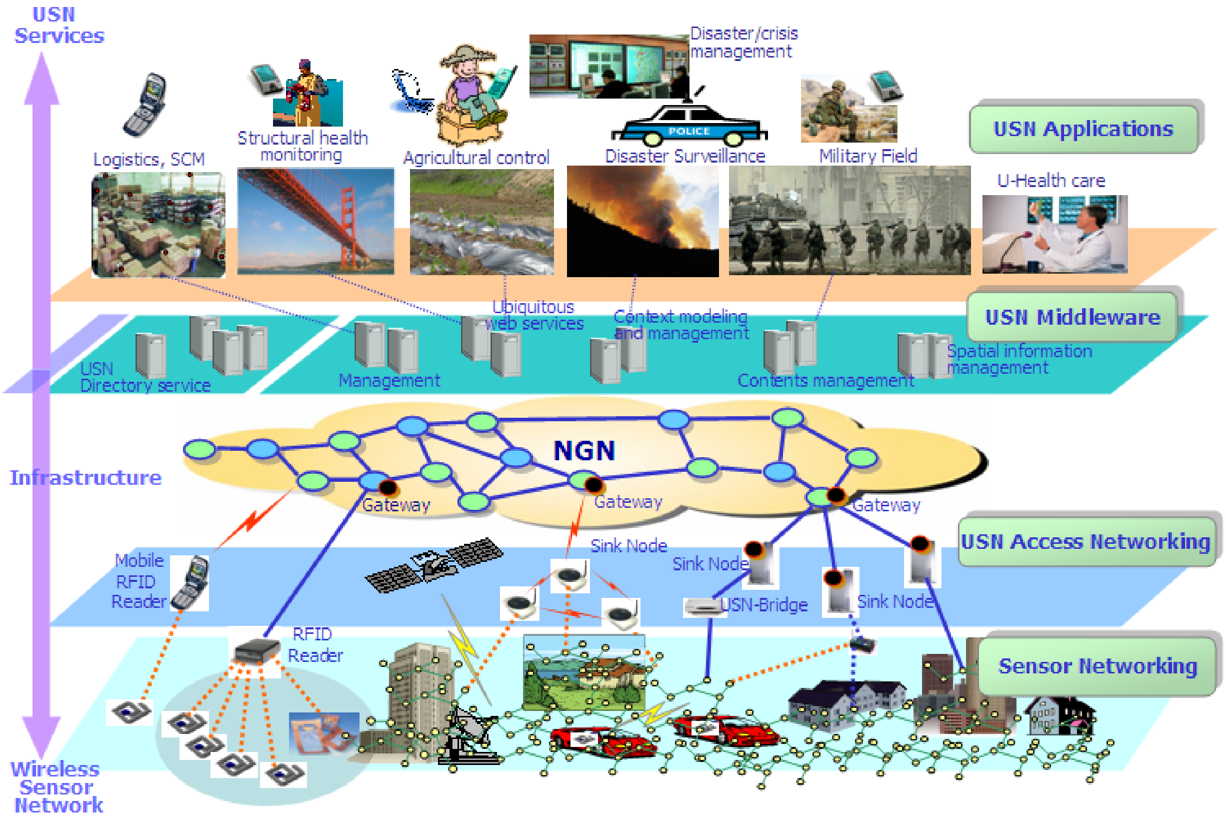
The term "ubiquitous" is derived from the Latin word *ubique* meaning "everywhere". But the literal interpretation of a USN—as meaning sensors on every single part of the globe, however remote—is not a realistic aim. Instead, a more reasonable definition is based on socio-economic, rather than geographical lines, and describes a technology which can be available "anywhere" (i.e., anywhere that it is useful and economically viable to expect to find a sensor), rather than "everywhere". The concept of availability is wider than just a geographical measure, and the expression "*anywhere, anytime, by anyone and anything*" (the "4A vision"[4]) has come to be used to illustrate the trend towards a ubiquitous network society.[5]

USNs have applications in both civilian and military fields. For civilian applications, these include environment and habitat monitoring, healthcare, home automation and intelligent transport systems.[6] The main components of a USN, as described in Figure 1, are:

- **Sensor Network**: Comprising sensors and an independent power source (e.g., battery, solar power). The sensors can then be used for collecting and transmitting information about their surrounding environment;
- **USN Access Network**: Intermediary or "sink nodes" collecting information from a group of sensors and facilitating communication with a control centre or with external entities;
- **Network Infrastructure**: likely to be based on a next-generation network (NGN);
- **USN Middleware**: Software for the collection and processing of large volumes of data;
- **USN Applications Platform**: A technology platform to enable the effective use of a USN in a particular industrial sector or application.[7]

The nodes may vary enormously in size and in cost and complexity. The medium that nodes use to communicate with the sink would vary according to the characteristics of the application. Depending on the

**Figure 1: Schematic Layers of a Ubiquitous Sensor Network**



*Source:* ITU NGN-GSI Rapporteur Group Meeting " Draft Recommendation *Y.USN-reqts*, "Requirements for support of USN applications and services in NGN environment," (Geneva, 11-21 September 2007), available at: http://www.itu.int/md/T05-NGN.GSI-DOC-0266/en (Note: Access restricted to TIES Users).

sensor type, the links between sensors may be provided by either wired or wireless communication. The transmission of sensor data using radio frequency might be used, for instance, in the tracking of goods in supply chain management. This application of radio frequency identification (including RFID tags with sensors) corresponds to the lower layers in the schematic model for USN as follows:

- **RFID Tags**: An RFID processor that may be either passive or active (with potentially read/write functions, wider communication ranges and independent power supplies). An active RFID chip is capable of two-way communication whereas a passive tag is read-only.
- **RFID Reader**: The reader senses and "reads" the information on the tag and passes it on for analysis
- **RFID Middleware**: Like the USN, the RFID network may have its own software for the collection and processing of data.

**Box 1: Characteristics of a USN**

- Small-scale sensor nodes;
- Limited power requirements that can be harvested (e.g., solar power) or stored (e.g., battery);
- Able to withstand harsh environmental conditions;
- Fault tolerant and designed to cope with high possibility of node failures;
- Support for mobility;
- Dynamic network topology;
- Able to withstand communication failures;
- Heterogeneity of nodes;
- Large scale of deployment

*Source:* Adapted from ETRI, Republic of Korea contribution to ITU NGN-GSI, Sept 2007, doc. 266.[8]

As illustrated in Figure 1, a USN is not simply a network but can be an intelligent information infrastructure used to support a multitude of different applications. USNs can deliver information to "anywhere, anytime, by anyone". But it is the ability to deliver the information also to "anything" which is groundbreaking.

Value is added to the information by using "context awareness", which comes from detecting, storing, processing and integrating situational and environmental information gathered from sensor tags and/or sensor nodes affixed to any object. For instance, context awareness may relate to where the object is located; whether it is moving or stationary; whether it is hot or cold, etc.

The characteristics of a USN are described in Box 1, which derives from a contribution from ETRI, Republic of Korea, to ITU's Next-Generation Networks – Global Standards Initiative (NGN-GSI).[9] The characteristics are diverse and therefore require a multi-disciplinary approach. For instance, the small scale of some sensor nodes (sometimes also referred to as "smart dust"; from a project at the University of California at Berkeley) can require working with nanotechnologies while the requirements to support mobility may need interworking with a range of different wireless standards such as 2G (e.g., GSM), 2.5G (e.g., GPRS) 3G/WiMAX (e.g., IMT) and other technologies like near-field communications. Furthermore, because a USN can provide a platform for such a diverse range of vertical applications, many of which have unique requirements, there is also a need to standardize common elements that can be shared between applications, in order to reduce costs.

## 3. TECHNICAL AND STANDARDS-BASED ISSUES

Each of the five layers of a USN (as outlined in Figure 1) has specific technical and standards-based challenges, and a number of different standards development organisations (SDOs) are involved in the work (see Figure 2). For instance, for the first layer of the USN (sensor nodes), the standards requirements include antenna and battery technology, interface, sensor operating system technology, which includes an energy-efficient information network architecture. For USNs, one of the most important standards issues is the development of protocols for sensor networks as well as inter-working with backbone network infrastructures, such as Next-General Networks (NGN).

Within ITU, USN standardization is being carried out under the auspices of the Next-Generation Network Global Standards Initiative (NGN-GSI). The topic was first considered in the context of ITU-T's Technology Watch function[10] and a work programme on USN was initiated at the February 2007 meeting of TSAG[11]. TSAG subsequently issued a liaison statement (LS 26) on the initiation of USN studies, aimed in particular at ITU-T Study Groups 13, 16, 17 and the Joint Coordination Activity on Networked aspects of IDentification (JCA-NID). A draft Recommendation Draft Recommendation *Y.USN-reqts*, "Requirements for support of USN applications and services in NGN environment,"[12] has been developed. At the most recent NGN-GSI cluster of meetings, held in Seoul, Republic of Korea, 14-25 January 2008, ETRI submitted a proposal (AVD-3375) to ITU-T Study Group 16 for a new study question on USN applications and services[13]. The proposal foresees a work programme of new and amended Recommendations for completion by 2010. This could form part of a larger programme of work on "NGN and beyond".

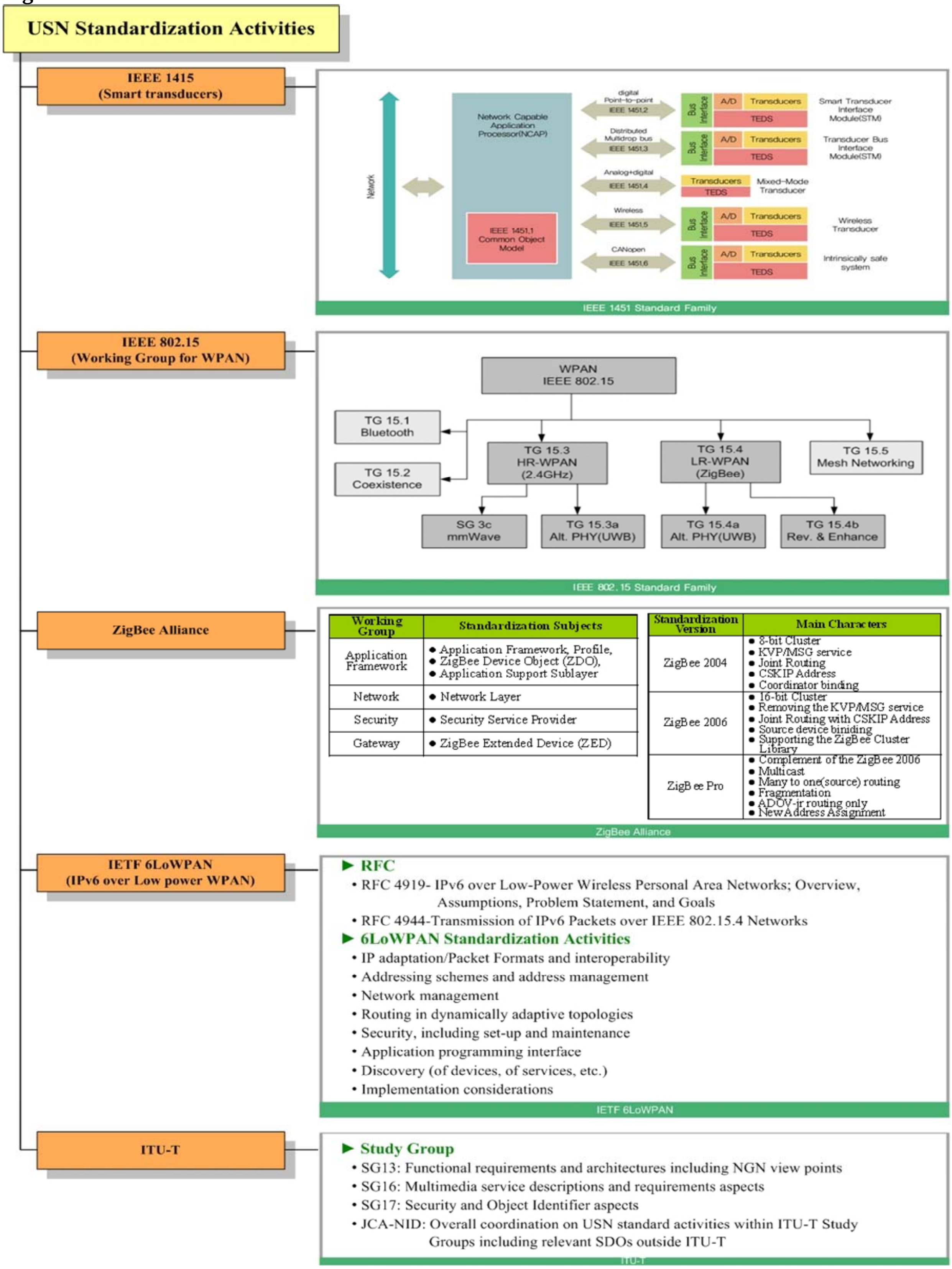
Closely related to ITU's work is that of SC 6 (Telecommunications and Information Exchange between Systems) of ISO/IEC JTC/1, where a number of proposals for work on USN have also been submitted.

A Ubiquitous Sensor Network can either be based on Internet Protocol (IP) or non-IP-based protocols. As an example of standardization work on the former, the 6LoWPAN (IPv6 based Low-power Wireless Personal Area Network) standard (more correctly, IPv6 over IEEE 802.15.4) provides for a communications network with limited power requirements suitable for wireless sensors (see Box 2).[14]

However, certain other applications may be more suited to a non-IP platform, especially for near-field communications and where speed of response and low power requirements are critical factors. ZigBee, which is an implementation of the IEEE 802.15.4 standard for wireless personal area networks (WPAN), provides such a suite of communication protocols. First released in December 2004, ZigBee is now supported by over 200 companies that belong to the ZigBee Alliance. Alternative technologies to ZigBee include UltraWideBand (UWB), Bluetooth, and WiBree, etc.

**Box 2: WPAN (Wireless Personal Area Network)**
A wireless personal area network (WPAN) is a personal, short distance area wireless network (typically extending up to 10 metres in all directions) for interconnecting devices centred around an individual person's workspace. WPANs address wireless networking and mobile computing devices such as PCs, PDAs, peripherals, cell phones, pagers and consumer electronics.

**Figure 2: USN standardization activities**



| Working Group | Standardization Subjects |
|---|---|
| Application Framework | • Application Framework, Profile,<br>• ZigBee Device Object (ZDO),<br>• Application Support Sublayer |
| Network | • Network Layer |
| Security | • Security Service Provider |
| Gateway | • ZigBee Extended Device (ZED) |

| Standardization Version | Main Characters |
|---|---|
| ZigBee 2004 | • 8-bit Cluster<br>• KVP/MSG service<br>• Joint Routing<br>• CSKIP Address<br>• Coordinator binding |
| ZigBee 2006 | • 16-bit Cluster<br>• Removing the KVP/MSG service<br>• Joint Routing with CSKIP Address<br>• Source device biniding<br>• Supporting the ZigBee Cluster Library |
| ZigBee Pro | • Complement of the ZigBee 2006<br>• Multicast<br>• Many to one(source) routing<br>• Fragmentation<br>• ADOV-jr routing only<br>• New Address Assignment |

ZigBee Alliance

▶ **RFC**

- RFC 4919- IPv6 over Low-Power Wireless Personal Area Networks; Overview, Assumptions, Problem Statement, and Goals
- RFC 4944-Transmission of IPv6 Packets over IEEE 802.15.4 Networks

▶ **6LoWPAN Standardization Activities**

- IP adaptation/Packet Formats and interoperability
- Addressing schemes and address management
- Network management
- Routing in dynamically adaptive topologies
- Security, including set-up and maintenance
- Application programming interface
- Discovery (of devices, of services, etc.)
- Implementation considerations

IETF 6LoWPAN

▶ **Study Group**

- SG13: Functional requirements and architectures including NGN view points
- SG16: Multimedia service descriptions and requirements aspects
- SG17: Security and Object Identifier aspects
- JCA-NID: Overall coordination on USN standard activities within ITU-T Study Groups including relevant SDOs outside ITU-T

ITU-T

*Source:* Adapted from http://www.zigbee.org/en/spec_download/zigbee_downloads.asp and from Young-Woon Kim (2007) "Review of UNS Standardization Activities", ETRI.

In addition, the IEEE 1451 standard is used to provide various low-cost transducer interfaces that convert energy between different elements of the USN.[15]

## Box 3: Sample applications of USNs

Ubiquitous Sensor Networks provide potentially endless opportunities in a diverse number of different applications, which include:

- **Intelligent Transportation Systems (ITS):** A network of sensors set up throughout a vehicle can interact with its surroundings to provide valuable feedback on local roads, weather and traffic conditions to the car driver, enabling adaptive drive systems to respond accordingly. For instance, this may involve automatic activation of braking systems or speed control via fuel management systems. Condition and event detection sensors can activate systems to maintain driver and passenger comfort and safety through the use of airbags and seatbelt pre-tensioning. Sensors for fatigue and mood monitoring based on driving conditions, driver behaviour and facial indicators can interact to ensure safe driving by activating warning systems or directly controlling the vehicle. A broad city-wide distributed sensor network could be accessed to indicate traffic flows, administer tolls or provide continually updated destination routing feedback to individual vehicles. The feedback may be based on global and local information, combining GPS information with cellular networks.[16]
- **Robotic landmine detection:** A sensor network could be used for the detection and removal or deactivation of landmines. The USN enables the safe removal of landmines in former war zones, reducing the risk to those involved in the removal process. The cost effectiveness of the network will aid in its application in developing countries, where the after-effects of war continue to take a toll on people living in areas still containing live explosives. The utilization of advanced sensor technology to detect explosives may help overcome difficulties in detection of un-encased landmines. For water-borne mines, an innovative application pioneered by the US Navy involves fitting sea-lions with detectors.[17]
- **Water catchment and eco-system monitoring:** A network of sensors can be utilized to monitor water flows into catchment areas and areas where access is difficult or expensive. This information can be combined with other sensor networks providing information on water quality and soil condition, together with long term weather forecasting to assist with the equitable and efficient distribution of water for irrigation and environmental purposes. Similar technology can be utilized to provide an early warning system for flood prone regions, particularly flash flooding.[18]
- **Real-time health monitoring:** A network of advanced bio-sensors can be developed using nanotechnology to conduct point-of-care testing and diagnosis for a broad variety of conditions. This technology will reduce delays in obtaining test results, thus having a direct bearing on patient recovery rates or even survival rates. On the basis of the sensed data, physicians can make a more rapid and accurate diagnosis and recommend the appropriate treatment. USN may also enable testing and early treatment in remote locations, as well as assist triage on location at accident or disaster sites.[19]
- **Bushfire response:** A low-cost distributed sensor network for environmental monitoring and disaster response could assist in responding to bushfires by using an integrated network of sensors combining on-the-ground sensors – monitoring local moisture levels, humidity, wind speed and direction – with satellite imagery to determine fire-risk levels in targeted regions and offering valuable information on the probable direction in which fires may spread. This type of USN can provide valuable understanding of bushfire development and assist authorities in organizing a coordinated disaster response by providing early warning for high risk areas.[20]
- **Remote Sensing in Disaster Management:** Remote sensing systems have proven to be invaluable sources of information that enable the disaster management community to make critical decisions based on information obtained from study of satellite imagery for better preparedness and initial assessments of the nature and magnitude of damage and destruction. Information derived from satellites can be combined with on-the-ground data from a USN. High-resolution remote sensing data is especially useful for documenting certain hazards, for determining where to locate response facilities and supplies, and for planning related facilities for reconstruction and relocation activities. Data availability and its timely delivery are crucial to saving lives and property during disasters, and technological developments are making positive contributions in this area. Some of the most significant progress in disaster reduction is being made in mitigation, using historical and contemporary remote sensing data in combination with other geospatial data sets as input to compute predictive models and early warning systems.[21]

*Source*: Adapted from http://www.ee.unimelb.edu.au/ISSNIP/apps/index.html.

## 4. USN APPLICATIONS: DETECTING, TRACKING, MONITORING

The unique potential and particular characteristics of sensor nodes and network infrastructure have encouraged researchers to identify potential applications in a diverse range of domains. Nevertheless, in most cases, applications can be assigned to one of the following three broad categories:

1) **Detection** – e.g., of temperatures passing a particular threshold, of intruders, of bushfires, of landmines in former war zones, etc.;

## Box 4: Monitoring volcanic eruptions with a Wireless Sensor Network

In a joint project with vulcanologists from three other universities, a team of computer scientists at Harvard University deployed a wireless USN at *Tungurahua* and at *Reventador*, two active and hazardous volcanoes in Ecuador.

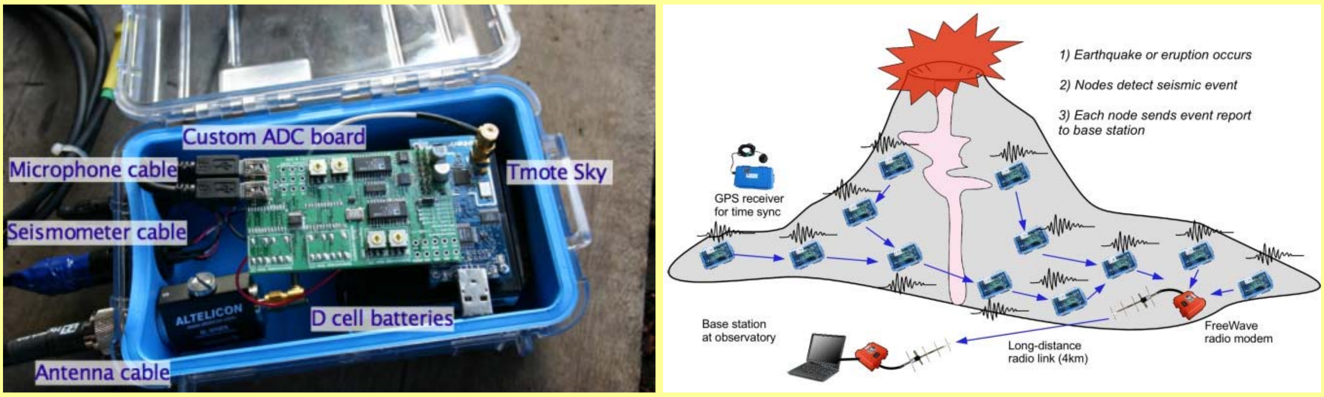


**Figure 3: Wireless seismic and acoustic sensor node (left) and volcano monitoring network architecture (right)**

Studying active volcanoes typically involves sensor arrays built to collect seismic and infrasonic (low-frequency acoustic) signals. This project was among the first to study the use of tiny, low-power wireless sensor nodes for geophysical studies, which have advantages in cost, size, weight and power supply over the traditionally used sensors. Just 16 sensor nodes, driven by conventional D cell batteries (see an example node in Figure 3, left side), were deployed over a 3 $km^2$ aperture on the upper flanks of the *Reventador* volcano. The system routed the collected data through a multi-hop network and over a long-distance radio link to an observatory, where a laptop logged the collected data, as can be seen in Figure 3, right side. Volcano research requires extremely high data quality and reliability: only one missed or corrupt sample can invalidate an entire record. Over three weeks, the network captured 230 volcanic events, producing useful data and allowing performance evaluation of large-scale sensor networks for collecting high-resolution volcanic data to facilitate scientific studies on volcanic source mechanisms and wave propagation laws. Similar architectures of sensor networks may be used to monitor and research different natural phenomena, as well as in the field of disaster detection and prevention.

*Source*: Adapted from http://www.eecs.harvard.edu/~mdw/proj/volcano/ and http://www.eecs.harvard.edu/~mdw/papers/volcano-ieeeic06.pdf.

2) **Tracking** – e.g., of items in supply chain management, of vehicles in intelligent transport systems, of cattle/beef in the food chain, of workers in dangerous work-environments such as mines or offshore platforms etc,
3) **Monitoring** – e.g., of a patient's blood pressure, of inhospitable environments such as volcanoes or hurricanes, of the structural health of bridges or buildings, or of the behaviour of animals in their indigenous habitat etc.

Domains in which USN are used include civil engineering, education, healthcare, agriculture, environmental monitoring, military, transport, disaster response and many more (See Box 3). In developing countries, specific applications could cover domains where network engineers face particular challenges such as unreliable power supply, reduced budgets or the danger of theft.[22] The falling prices of sensor units (already well below US$100) and RFID tags (to below 5 US cents) is greatly increasing a range of potential applications. Furthermore, the possibility of operating independently from electricity networks, by using conventional batteries, or – depending upon availability – solar or geothermal power as energy supplies, can make sensor networks more widely available in different environments.

Irrespective of whether used in developed or developing countries, USNs need to be adaptable and highly application-specific. Some of the design decisions that must be made before the deployment of a USN, include, *inter alia*:

- the types of sensors to be employed (e.g., chemical sensors to monitor hydrogen sulphide concentration in a gas pipeline or motion sensors deployed in a area with seismic activity);
- the choice of the communication protocols and medium (depending on distance, transmission rate); and

**Figure 4: Countries most at risk from natural disasters related to climate change**

| Drought | Flood | Storm | Coastal (<1m)[a] | Coastal (<5m)[a] | Agriculture |
|---|---|---|---|---|---|
| Malawi | Bangladesh | Philippines | All low-lying island states | All low-lying island states | Sudan |
| Ethiopia | China | Bangladesh | Vietnam | Netherlands | Senegal |
| Zimbabwe | India | Madagascar | Egypt | Japan | Zimbabwe |
| India | Cambodia | Vietnam | Tunisia | Bangladesh | Mali |
| Mozambique | Mozambique | Moldova[b] | Indonesia | Philippines | Zambia |
| Niger | Lao PDR | Mongolia[b] | Mauritania | Egypt | Morocco |
| Mauritania | Pakistan | Haiti | China | Brazil | Niger |
| Eritrea | Sri Lanka | Samoa | Mexico | Venezuela | India |
| Sudan | Thailand | Tonga | Myanmar | Senegal | Malawi |
| Chad | Vietnam | China | Bangladesh | Fiji | Algeria |
| Kenya | Benin | Honduras | Senegal | Vietnam | Ethiopia |
| Iran | Rwanda | Fiji | Libya | Denmark | Pakistan |

*Notes:* a. Metres above sea-level. B. Winter storms. Shaded countries are Least Developed Countries.
*Source:* World Bank, October 2007, IDA and climate change: Making climate action work for development.

- on the energy supply of the nodes (e.g., can batteries be easily replaced? This might be possible in a light sensor in the house, but not if sensors are deployed in a minefield).

## 5. USN IMPLICATIONS FOR DEVELOPING COUNTRIES

Although most of the R&D and standardization work on USN is taking place in developed countries, it is arguably developing countries that will benefit most from the technology, both on the supply and demand sides.

For example when USNs are based on RFID technologies, on the demand side, it is likely that the manufacturing of USN components and systems – primarily RFID chips and sensors– will quickly become a commodity business, with a high degree of automation. This could suit the low-labour cost locations of developing countries. As a specific example, China has emerged as a leading manufacturer of RFID chips, in part as a result of the demands of developed country retailers such as like Wal-Mart — for whom it is a major supplier as the source of some US$100 billion worth of goods in 2005.[23] In addition, those developing countries that have an indigenous software programming sector (e.g., India, Philippines, Vietnam) are also likely to benefit from contracts for development of USN middleware, requiring a high-level of customization for specific applications.

On the demand-side, it is also likely that developing countries will be major beneficiaries, especially in the field of environmental monitoring. As shown in Figure 4, the countries most at risk from natural disasters related to climate change (e.g., drought, floods, storms, coastal flooding, etc) are mainly developing ones, with particular vulnerabilities among least developed countries (LDCs) and small island developing states (SIDS). In other applications, like landmine clearance or agricultural management, developing countries may be the main users of USN technology in the long-term.

This report in the ITU-T Technology Watch Briefing Report series has been prepared for information and discussion. For more information, or to comment or make additional inputs to the report, please respond by email to tsbtechwatch@itu.int.

## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| 2G | Second Generation mobile phone technology |
| 3D | Three Dimensional |
| 3G | Third Generation mobile phone technology |
| 4A | Anywhere, Anytime, by Anyone and Anything |
| A/D | Analogue to Digital |
| CALM | Continuous Air-interface for Long and Medium-range |
| ETRI | Electronics and Telecommunications Research Institute (Republic of Korea) |
| GPRS | General Packet Radio Service (a mobile phone technology) |
| GPS | Global Positioning by Satellite |
| GSM | Global System for Mobile communications (a mobile phone technology) |
| HR-WPAN | High Rate – Wireless Personal Area Network |
| ICTs | Information and Communications Technologies |
| ID | Identity or Identification |
| IDA | International Development Agency (World Bank Group) |
| IEC | International Electrotechnical Commission |
| IEEE | Originally: Institute of Electrical and Electronic and Engineers (now simply IEEE) |
| IMT | International Mobile Telecommunications (formerly IMT-2000) |
| IP | Internet Protocol |
| IPv6 | Internet Protocol Version 6 |
| ISO | International Organisation for Standardization |
| ITAHK | Information Technology Association of Hong Kong |
| ITS | Intelligent Transport Systems |
| ITU-T | International Telecommunication Union Telecommunication Standardization Sector |
| JCA-NID | Joint Coordination Activity – Networked aspects of IDentification |
| JTC1 | Joint Technical Committee 1 |
| KVP | Key Value Pair |
| LDC | Least Developed Country |
| LoWPAN | Low-power Wireless Personal Area Network |
| LR-WPAN | Low Rate – Wireless Personal Area Network |
| MIC Japan | Ministry of Internal Affairs and Communications, Japan |
| MSG | Message |
| NCAP | Network Capable Application Processor |
| NGN | Next-Generation Network |
| NGN-GSI | NGN-Global Standards Initiative |
| PC | Personal Computer |
| PDA | Personal Digital Assistant |
| PHY | Physical layer |
| R&D | Research and Development |
| RFC | Request For Comments |
| RFID | Radio-frequency identification |
| SCM | Supply Chain Management |
| SDO | Standards Development Organisation |
| SG | Study Group |
| SIDS | Small Island Developing States |
| STM | Smart Transducer interface Module |
| TEDS | Transducer Electronic Data Sheet |
| TIES | Telecom Information Exchanges Services |
| TG | Task Group |
| TSAG | Telecommunication Standardization Advisory Group (of ITU-T) |
| U | Ubiquitous, as in “uHealth” or “uCity” |
| UNU | United Nations University |
| USN | Ubiquitous Sensor Network |
| UWB | UltraWideBand |

| | |
|---|---|
| WiMAX | Wireless Interoperability for Microwave Access |
| WPAN | Wireless Personal Area Network |
| WSIS | World Summit on the Information Society |
| WSN | Wireless Sensor Network |
| ZDO | ZigBee Device Object |
| ZED | ZigBee Extended Device |

## ENDNOTES AND REFERENCES FOR FURTHER READING

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[1] The term “Invisible Computer” comes from a book of the same name by Donald Norman (1998). “Pervasive computing” is, *inter alia*, the name of a magazine published by IEEE. The term “Ubiquitous computing” is usually ascribed to Marc Weiser, who coined the term in 1991 to describe a “third wave” in computing (after mainframes and PCs), which would usher in an era in which computing devices will be embedded in everyday objects, invisibly at work in the environment around us.

[2] The term “ambient intelligence” was originally popularized by Philips and relates to a human-centric computer/communications environment where the intelligence is embedded, context-aware, personalized, adaptive and anticipatory.

[3] The “Internet of Things” was the title of the 2005 ITU Internet Report, published during the Tunis Phase of WSIS. The term refers to the connection of everyday objects and devices to electronic networks. It was also the topic of an Economist special report entitled “A world of connections”, on April 26 2007.

[4] See Kelly, Tim (2006) “The 4A vision: anytime, anywhere, by anyone and anything”, presentation at ITAHK luncheon, 8 December 2005, available at: http://www.cahk.hk/Event/30/images/Luncheon_Dec2005_Powerpoint.pdf.

[5] “The Ubiquitous Network Society” was the theme of a WSIS Thematic Event, organized by ITU, MIC Japan and UNU, on 16-17 May 2005. The chairman’s report is available at: http://www.itu.int/wsis/docs2/thematic/japan/chairman-report.pdf.

[6] See ITU Technology Watch Briefing Report #1 on Intelligent Transport Systems and CALM, available at: http://www.itu.int/oth/T2301000001/en.

[7] Adapted from Kun-yung Ahn (Sept 2006), “RFID/USN in Korea,”, Presentation to Seoul Members Meeting Open House, available at: http://www.zigbee.org/imwp/idms/popups/pop_download.asp?contentID=9454

[8] See “Draft Recommendation *Y.USN-reqts*, "Requirements for support of USN applications and services in NGN environment," (Geneva, 11-21 September 2007), submitted by ETRI, Republic of Korea, at: http://www.itu.int/md/T05-NGN.GSI-DOC-0266/en.

[9] See: “Proposal for a new draft Recommendation on NGN service requirements to support NGN”, submitted by ETRI, Republic of Korea, to NGN-GSI Rapporteur Group meeting, 11-21 September 2007, document NGN-GSI/ C751, available at: http://www.itu.int/md/T05-NGN.GSI-C-0751/en.

[10] Technology Watch established a USN correspondence group in August 2006. For more information, see: http://www.itu.int/ITU-T/techwatch/usn-cg.html.

[11] The proposal was initiated by a contribution from the Electronics and Telecommunication Research Institute (ETRI) of the Republic of Korea in TSAG C.22, entitled “A preliminary study of the Ubiquitous Sensor Network”, available at: http://www.itu.int/md/T05-TSAG-C-0022/en.

[12] Available at: http://www.itu.int/md/T05-NGN.GSI-DOC-0266/en (Note: Access restricted to TIES Users).

[13] See: http://www.itu.int/md/T05-SG16-080422-TD-WP2-0542/en.

[14] For more information on 6LoWPAN, see: http://6lowpan.net/. A recent assessment is available in N. Kushalnagar, et. al, RFC 4919: IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement, and Goals, IETF, Aug. 2007, at: http://tools.ietf.org/html/rfc4919

[15] For more information, see ETRI Contribution to Study Group 16, C.188, “Review of USN Standardization Activities”, available at: http://www.itu.int/md/T05-SG16-C-0188.

[16] See ITU-T (October 2007) Technology Watch Briefing Report on ITS and CALM.

[17] See Habib, Maki (2007) “Controlled biological and biomimetic systems for landmine detection”, in Biosensors and Bioelectronics, Volume 23, Issue 1, 30 August 2007, Pages 1-18

[18] See SEAMONSTER, (at: http://robfatland.net/seamonster/index.php?title=Basics) a smart sensor web project designed to support collaborative environmental science with near-real-time recovery of environmental data. The initial geographic focus of this project is the Lemon Creek watershed near Juneau, Alaska.

[19] The Department of Computer Science at the University of Virginia has developed a wireless sensor network for smart healthcare, called AlarmNet – “Assisted-Living And Residential Monitoring Network”. For more information on AlarmNet and sensor networks for healthcare, see: http://www.cs.virginia.edu/wsn/medical/.

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[20] An Australian company, Telepathx Ltd (http://www.telepathx.com/solutions_fire.htm), has implemented a reactive sensor network for real-time fire ignition monitoring, offering virtual 3D mapping and modeling, as well as communication links for fire notification via GSM, CDMA, 3G etc.

[21] A recent ITU workshop (11 December 2007) explored the critical role of remote sensing technologies in providing timely and quality information that facilitates the work of the disaster management community. For more information, see: http://www.itu.int/ITU-D/emergencytelecoms/events/global_forum/remotesensing.html.

[22] See Waltenegus Dargie and Marco Zimmerling. 2007. “Wireless Sensor Networks in the Context of Developing Countries” (invited paper from researchers at TU Dresden). The 3rd IFIP World Information Technology Forum. Addis Ababa, Ethiopia, August 22-24, 2007.

[23] See ITU (2005) “Internet of Things”, summary online and full report available for purchase online at: www.itu.int/internetofthings.