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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Future networks

Smart ubiquitous networks – Overview

Recommendation ITU-T Y.3041

ITU-T

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Recommendation ITU-T Y.3041

Smart ubiquitous networks – Overview

Summary

Recommendation ITU-T Y.3041 describes the necessity of smart ubiquitous networks (SUN) as a short-term realization of future networks. It identifies SUN objectives and the high-level requirements for providing relevant network and service capabilities in terms of the smart and ubiquitous aspects of networks. This Recommendation provides an overview of various capabilities to support the smart and ubiquitous aspects of networks, such as context awareness, content awareness, smart resource management, programmability, autonomic network management and ubiquity. Details of each subject area will be described in separate Recommendations.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y.3041	2013-04-13	13

Keywords

Autonomic network management, content awareness, context awareness, programmability, smart resource management, SUN, ubiquity.

FOREWORD

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Smart ubiquitous networks – Overview

1 Scope

This Recommendation provides an overview of smart ubiquitous networks (SUN), which are a short-term realization of future networks (FNs). This Recommendation covers the following:

- the necessity of the SUN from the perspective of devices, network innovation and social considerations;
- objectives of the SUN;
- SUN capabilities and high-level requirements for the SUN, including awareness aspects.

This Recommendation provides an overview of the SUN; details of each subject area will be developed in separate Recommendations.

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.2701] Recommendation ITU-T Y.2701 (2007), *Security requirements for NGN release 1*.

[ITU-T Y.3001] Recommendation ITU-T Y.3001 (2011), *Future networks: Objectives and design goals*.

[ITU-T Y.3042] Recommendation ITU-T Y.3042 (2013), *Smart ubiquitous networks – Smart traffic control and resource management functions*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 content [b-ITU-T X.1161]: Information created by individuals, institutions and technology to benefit audiences in contexts that they value.

3.1.2 context [b-ITU-T Y.2002]: The information that can be used to characterize the environment of a user.

NOTE – Context information may include where the user is, what resources (devices, access points, noise level, bandwidth, etc.) are near the user, at what time the user is moving, interaction history between person and objects, etc. According to specific applications, context information can be updated.

3.1.3 context awareness [b-ITU-T Y.2201]: Context awareness is a capability to determine or influence a next action in telecommunication or process by referring to the status of relevant entities, which form a coherent environment as a context.

3.1.4 fair usage [ITU-T Y.3042]: Equal treatment for the same service(s), including application(s), between different users (e.g., end-user applications) with the same service level agreement (SLA).

3.1.5 object [b-ITU-T Y.2002]: An intrinsic representation of an entity that is described at an appropriate level of abstraction in terms of its attributes and functions.

NOTE 1 – An object is characterized by its behaviour. An object is distinct from any other object. An object interacts with its environment including other objects at its interaction points. An object is informally said to perform functions and offer services (an object which makes a function available is said to offer a service). For modelling purposes, these functions and services are specified in terms of the behaviour of the object and of its interfaces. An object can perform more than one function. A function can be performed by the cooperation of several objects.

NOTE 2 – Objects include terminal devices (e.g., used by a person to access the network such as mobile phones, Personal computers, etc.), remote monitoring devices (e.g., cameras, sensors, etc.), information devices (e.g., content delivery server), products, contents, and resources.

3.1.6 thing [b-ITU-T Y.2060]: 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.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 smart ubiquitous networks (SUN): IP-based packet networks that can provide transport and delivery of a wide range of existing and emerging services to people and things. The services provided by the SUN can cover aspects such as control, processing and storage.

NOTE 1 – The network is smart in the sense that it is knowledgeable, context-aware, adaptable, autonomous and programmable, and can perform services effectively and securely.

NOTE 2 – The network is ubiquitous in the sense that it allows access anytime, anywhere, through varied access technologies, access devices, including end-user devices, and human-machine interfaces.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3DTV	Three Dimensional Television
API	Application Programming Interface
CPU	Central Processing Unit
FN	Future Network
GPS	Global Positioning System
HDTV	High Definition Television
ICT	Information and Communications Technology
IP	Internet Protocol
ITS	Intelligent Transportation System
NGN	Next Generation Network
QoE	Quality of Experience
QoS	Quality of Service
SLA	Service Level Agreement
SUN	Smart Ubiquitous Networks

TCP Transmission Control Protocol

UDP User Datagram Protocol

USN Ubiquitous Sensor Network

WiFi Wireless Fidelity

WiMax Worldwide Interoperability for Microwave Access

5 Conventions

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "is prohibited from" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "is not recommended" indicate a requirement which is not recommended but which is not specifically prohibited. Thus, conformance with this Recommendation can still be claimed even if this requirement is present.

The keywords "can optionally" indicate 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 this Recommendation.

6 Necessity of the SUN

Because of developments in information and communications technology (ICT), many end-user devices, networks and services have been acquiring more complicated features and capabilities. Telecommunication infrastructures, especially IP-based infrastructures, have been continuously requested to extend capabilities to meet requirements for such complicated features. At the same time, operators and providers are increasingly demanding with regard to efficient and productive use of their resources.

This clause provides background information of the current telecommunication industry and the motivation for requiring capabilities, which are referred to as the SUN in clause 7.

6.1 Smart and ubiquitous devices

ICT developments have had a wide impact in telecommunications in general, and especially on end-user devices in terms not only of their physical appearance (e.g., size and media display), but also of their services and applications (including communication capabilities such as multiple network connections). Devices termed as "smart" are already available, generating smart and ubiquitous environments. The first device is the smartphone, providing a communication and service platform for an individual person. The second device is the smart TV, being a media gateway for an end-user living environment. The third device is the smart small device such as the sensor and actuator, providing connections to anything.

Smartphones are one of the key drivers in creating smart and ubiquitous environments, with their extended features including "always-on" connections. Smartphones use mobile accesses (e.g., 2G, 3G or 4G) and/or wireless accesses (e.g., WiFi and WiMax) in a separate and/or integrated manner (i.e., the multiple-connection capability). Powerful processing with a high-resolution tiny camera

allows an end user to become a prosumer (producer and consumer) for multimedia contents. The tiny-device technology (e.g., reading bar codes and sensor signals) allows the smartphones to be used for ubiquitous connection environments such as ubiquitous sensor networks (USNs). Such multiple-connection capability and tiny-devices technology enable the smartphone to be a personal handheld gateway and a smart gadget without limitations of time and space.

In addition to being digital, a smart TV is equipped with smart capabilities to provide bidirectional service features, such as receiving TV programmes and contents from servers and sending contents (e.g., web-based multimedia). In addition, a smart TV should support an "always-on" connection because it works as a smart home gateway for communication for devices both inside and outside the home. Furthermore, extension of 3D quality video in the smart TV (i.e., 3D smart TV) requests much more bandwidth in bidirectional ways, which causes concerns about the huge volume of data.

Finally, smart small devices contribute significantly to expediting ICT convergence with other industries (e.g., ITS, e-health and smart grid). In addition, these devices provide status information on an end user (human being); for example, in the case of an e-health application, the health status of patients can be known. Since these devices generally use narrow-band connections over a short-distance-range wireless technology, it has been assumed that this cannot cause any further problems on the networks. However, the significance of data from smart small devices (e.g., sensitivity and significance of e-health data related to the patient) should be evaluated to ensure correct delivery by the real-time method with high priority.

Certain combinations of these devices require more complicated, sensitive and differentiated treatment of communication requirements. For example, a specific content would be delivered to the smartphone in abstracted resolution but delivered in very high resolution to the 3D smart TV. Further, the content should be available for both devices with seamless mobility.

Therefore, it is necessary to provide ubiquitous connectivity with smart capabilities to deal with the communication requirements of smartphones, smart TV and smart small devices, and to include efficient and effective management of resources.

6.2 Enhancement of networking capability

Deployment of smart and ubiquitous devices and advancement of the information society require better IP-based networks, as described in clause 6.1.

In addition, service delivery environments become more complex according to ICT developments, as follows:

- various media types (e.g., video, audio and different codecs) with a different quality of service (QoS)/quality of experience (QoE) which impact on the bandwidth reservation;
- different accessing policies, even in the same user device, depending on connecting capabilities with multiple interfaces and/or pricing policy;
- differentiated delivery according to the delivery policy and seamless handover among these different devices.

Another important issue caused by smart devices is the volume of data traffic, referred to as "data explosion"; an issue that is becoming an area of serious concern. Data explosion represents an enormous growth in data traffic to be handled. It is leading network operators towards negative growth because only a few users and providers for specific services and applications generate a large amount of traffic, thereby monopolizing almost all network resources. This monopolization of network resources (e.g., bandwidth and the number of sessions) by a few users prevents network operators from making proper arrangements and offering appropriate network resources to remaining users. In addition, such a monopolization leaves the majority of service and application users dissatisfied because of degradation of service quality. Monopolization may create an obstacle for further development of smart devices and their services. It is recognized that network resources

should not be dedicated to a specific user or a limited number of users but be common infrastructures for all users.

It is therefore necessary to provide smart communication capabilities and mechanisms for arrangement and management of resources, including traffic control, to ensure that service requirements take into account various characteristics from differentiated media types, accessing and delivery polices.

6.3 Protection of the information society

In developing the SUN, the inclusion of technical capabilities designed to minimize vulnerabilities in ICT infrastructures to improve cyber security should be taken into account.

7 Objectives of the SUN

Considering the four objectives of FNs identified in [ITU-T Y.3001], further enhancements of IP-based networks are anticipated to take into account the following: service awareness, data awareness, environmental awareness, and social and economic awareness (see clause 7 of [ITU-T Y.3001] for details). To achieve these objectives, it is necessary to identify feasible technologies for early realization considering evolutional approaches in existing IP-based networks. Hence, this Recommendation introduces the SUN as a short-term realization of technologies identified in FNs.

Taking into account emerging trends described in clause 6, it is anticipated that existing IP-based networks should be enhanced in the following ways:

1) Smart and simple ways for the user using various telecommunication/ICT services, even with limited knowledge of given environments, such as device features and configurations, network configurations and capabilities (accesses and backbone) and service features;

2) Smart and convenient ways for a network/service provider to configure, use, operate and manage telecommunication/ICT resources, while providing relevant capabilities in order to meet the user's dynamic requirements such as change of connectivity and service delivery points (e.g., from mobile to fixed device) and modification of user service preferences;

3) Dynamic and flexible ways for network and service provider provision of their services by considering the status of context from networks, services, devices, processes, storage and contents.

Considering the above rationale, the objectives of the SUN are identified as following two directions:

1) One objective of the SUN is the enhancement of the networking capabilities of IP-based networks through optimized and efficient use of various resources (e.g., resources for networks, services and end-user devices), not only for human beings but also for things and objects. The optimized and efficient use of resources should be carried out through smart resource management including QoS/QoE, security and mobility taking into account various user behaviours, end-user device capabilities, network/service capabilities and media types.

2) The second objective of the SUN is the support of various services and applications using smart and ubiquitous communications to network and service providers. To support this objective, it is essential to know the status of networks and services, including end users and contents. Status should be acknowledged by analysis of collected information from involved functional entities of IP-based networks, including end-user preferences. Thus, smart communications should be supported by assessment of collected information about the status of the associated contexts. Ubiquitous communications should be provided by connection capabilities supporting various different levels of mobility (e.g., nomadism and seamless handovers) and heterogeneous communication interfaces taking into account status of locations, network accesses, devices and service level agreement (SLA).

8 Capabilities and requirements of SUN

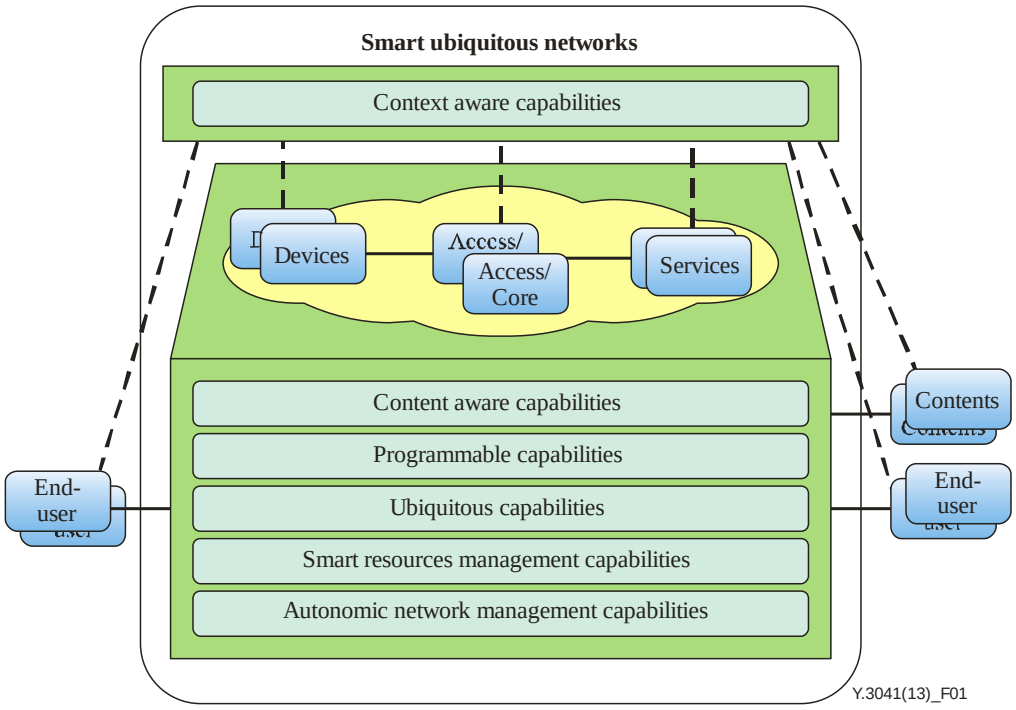
From objectives shown in clause 7, information necessary for the SUN is identified as follows:

- Information from end user about the status of end user (e.g., location, situation such as driving, attending music concert) to support adaptable, autonomous and programmable service delivery;
- Information from end-user devices about the status of end-user devices to support adaptable, autonomous and programmable networks, attachment configurations and service delivery;
- Information from networks about the status of networks (e.g., status and environments of access nodes and backbone transport-related nodes) to support adaptable, autonomous and programmable networks;
- Information from services about the status of service provision (e.g., service capabilities, service configurations including status of servers and storage) to support adaptable, autonomous and programmable service configuration;
- Information from contents about the content-related context (e.g., status and environments of contents in terms of media format, availability and properties).

Figure 1 shows the six capabilities to realize the SUN. They are:

- context-awareness capabilities
- content-awareness capabilities
- programmable capabilities
- smart resource management capabilities
- autonomic network management capabilities
- ubiquitous capabilities.

The following subclauses describe capabilities and high-level requirements.



NOTE 1 – Dotted lines indicate links to collect context-awareness information from the blue parts. Solid lines indicate links to deliver media.

NOTE 2 – Yellow cloud indicates a set of entities which deploy smart and ubiquitous capabilities.

Figure 1 – Capabilities of SUN

8.1 Context-awareness capability

A context-awareness capability is an ability to detect changes in the physical status of devices. Monitoring systems using sensors, and location-based services using GPS, are example technologies to support the context-awareness capability. This capability enables networks to dynamically capture context information and monitor the context change in order to be adaptive based on user characteristics and environment. The information for context awareness can be used for other capabilities such as context-aware content delivery.

NOTE − Application developers want their applications to be dynamically adaptable to context information coming from devices, services, networks and users. However, current networks do not have sufficient capabilities to monitor such context information, which is static in time and can be modified in time, and to adapt its behaviour automatically according to context changes.

The context-awareness capabilities of the SUN include:

- **Context gathering**: Collecting context information from distributed entities (e.g., end users, end devices, network entities and time);
- **Context repository**: Storing the generated contexts and retrieving those contexts whenever necessary;
- **Context analysis**: Analysing context information, providing statistical analysis, and changing it to the available format in order to properly use the information;
- **Context prediction**: Preparing for upcoming situations by analysing information;
- **Context sharing**: Securing delivery and update of context information to the entities which request the context information.

Context-awareness capabilities in SUN have the following requirements:

- SUN are required to collect context information from context sources;
- SUN are required to store and update context information in a database that deals with frequent changes and to reuse this context;
- SUN are required to analyse and interpret the captured information in order to identify or discover what content and services should be provided to users;
- SUN are required to prohibit illegal usage of context information.

8.2 Content-awareness capability

The content-awareness capability is an ability to identify, retrieve and deliver contents efficiently based on content-related information considering location and/or user. This capability provides personalized content-delivery services based on the user's situation and an optimized content delivery service. Network-side content caching and delivery in a node close to users also provides a high-quality video streaming service for explosive content requests. The information for content awareness can be used for other capabilities such as content-aware smart resource management.

NOTE – Following the emergence of smart devices, the explosive increase in the number of location-dependent contents is forcing great overload on the hosts that are providing contents. Even worse, the networks are sending the same contents redundantly because they cannot know 'what' they are forwarding. These delivery inefficiencies of current networks are requiring networks to change the basis of networking to become more knowledgeable about what they are delivering.

The content-awareness capabilities of the SUN include:

- **Content discovery**: Discovery of the best-fit content and content storage according to the content metadata or the location of users;
- **Content caching**: Storing and caching the content in local storage;
- **Dynamic content distribution**: Dynamically distributing contents that are in caches and storage in the network according to traffic load and usage, user location considering QoS, and traffic optimization.

Content-awareness capabilities in the SUN have the following requirements:

- SUN are required to identify and deliver the contents independent of location and the users demanding the contents;
- SUN are required to optimize content delivery through content caching at a nearer node;
- SUN are required to support distributed nodes in the network to keep a lot of contents and retrieve them;
- SUN are required to distribute contents and store the contents by managing content metadata;
- SUN are required to aggregate traffic and control paths for optimizing the content traffic traversed in the network.

8.3 Programmable capability

Programmable capability is an ability that can change software, behaviour and functions of the network by changing the network's program. This capability allows development and deployment of new, simple network services and enables networks to build up virtualized networks using associated resources to support the services via open interfaces. It makes innovative satisfaction of users' demand through adding flexibility into networks.

NOTE – Since going into the contents-based "services explosion" era requires a large capacity to transport, deliver and process, collaboration between service and transport functions is necessary in order to innovatively satisfy the user's demand. Collaboration requires that both service and transport functions should have enough capabilities to exchange resource-level information and to build up virtualized networks using associated resources to support the services.

Programmable capabilities include:

- **Open service/network APIs**: Supporting development and deployment of services as well as relevant monitoring and control capabilities in terms of services and/or networks according to requests;
- **Virtualization**: Enabling abstraction of physical resources and logically isolated resource partitions over shared physical network infrastructures and the aggregation of multiple resources;
- **Federation**: Interconnecting among inter-domain networks through defining and providing interfaces for control, service routing, logging, accounting and metadata among networks.

The programmable capabilities in the SUN have the following requirements:

- SUN are required to support open programmable interfaces;
- SUN are required to interconnect among inter-domain networks via APIs for supporting grouping users;
- SUN are required to support rapid creation and deployment of new network services;
- It is recommended that the SUN support virtualized networks using relevant resources.

8.4 Smart resource-management capability

The smart resource-management capability is an ability to provide fair usage of resources through more transparent and accurate arrangement of various types of resources (e.g., bandwidth, memory, storage and computing power) and their management in a network [ITU-T Y.3042].

NOTE 1 – A lot of new emerging services (e.g., smart TV, HDTV, 3DTV and video streaming) require the network to allocate large bandwidth. However, because the conventional IP network was designed to allocate the same bandwidth for each TCP flow, this could not provide fair usage of resources by hosts or applications that generate and use multiple TCP flows or UDP. It means that service disparity could happen. Some flows belonging to other users could experience service degradation and even service failures due to the lack of affordable resources.

Smart resource management capabilities include:

- **Smart resource monitoring**: Checking resources of the network entity and interface to optimally allocate resources;
- **Smart resource analysis**: Determining an appropriate resource for each user and service based on monitoring data and policies;
- **Smart resource control**: Allocating a resource for each flow, user and service.

NOTE 2 – Per-user flow management – by using per-user fair queuing, all users share the same bandwidth even if one particular user generates multiple flows to download content. If congestion does not occur, users can use network bandwidth or resources as much as they want.

Smart resource management capabilities in the SUN have the following requirements:

- SUN are required to support control and management of various types of resources including bandwidth;
- SUN are required to monitor and control the usage of resources in order to meet multiple users with different QoS/QoE requirements.

8.5 Autonomic network management capability

The autonomic network management capability is an ability for dynamic adaptation (i.e., self-adaptive, reorganization and reconfiguration), of the network and underlying systems according to the network running conditions and the state, as well as the economical and societal needs, of the users.

NOTE – Autonomic principles in network management are introduced in order to address the complexity of information and communication systems. In an autonomic environment, the network itself can detect, diagnose and repair failures and adapt its behaviour according to network policies. Autonomic monitoring is a process since it allows network components to assess their own state and the overall network conditions. However, predefining the monitoring scheme can be inefficient in heterogeneous environments, taking into consideration the constant changes in the network topology and the diversity of the interconnected systems.

Autonomic network management capabilities include:

- **Self-configuration**: Automatic configuration of network components without manual intervention;
- **Self-optimization**: Automatic monitoring and reallocation of resources to ensure the optimal functioning with respect to the defined requirements (e.g., predefined policy for energy consumption);
- **Self-protection**: Proactive identification of arbitrary attacks such as withholding, modifying and disclosing the private information and protection against them;
- **Self-healing**: Automatic detection, diagnosis of, and recovery from failures due to energy failure or malfunctions resulting from some software bugs;
- **Self-organization**: Automatically re-establishing connectivity according to topology and position, and allowing data to be disseminated and aggregated.

Autonomic network management in the SUN has the following requirements:

- SUN are required to monitor components within a network to be continuously adapted, in a flexible manner;
- SUN are required to efficiently sense changes in network conditions and the level of provided services and proceed to corrective actions taking into account monitored data exchanged by autonomic nodes;
- SUN are required to easily use context-aware information in order to take decisions according to the specified administrators' policies.

8.6 Ubiquitous capability

The ubiquitous capability is an ability to provide seamless communications between persons, between objects, and between persons and objects while they move from one location to another. To provide anywhere, anytime services, ubiquitous capability supports handovers and roaming in networks, no service interruption during device changing, and recognition through interactivity between humans and objects in the ubiquitous environment with various types of objects, heterogeneous interfaces and networks.

NOTE – There are many different kinds of devices connecting to the networks. The end points are not always human beings but may be objects such as devices/machines, and then expanding to small objects and parts of objects which enable detection of environmental status and sensory information. Some objects are dynamically moving with multi-functions/interfaces.

Ubiquitous capabilities include:

- **Adaptedness**: Support of dynamic changes of environments with the help of context awareness;
- **Seamlessness**: Mobility supported at different domains and layers (e.g., user/device mobility, network mobility, service mobility, content mobility);

- **Multiple-objects connectivity**: Various types of communications among objects as well as humans;
- **Ubiquitous access**: Accessing networks with heterogeneous/multiple interfaces as well as contents independent of location in fixed/mobile environment.

Ubiquitousness in the SUN has the following requirements:

- SUN are required to support innumerable numbers of computing devices embedded in almost everything around us; platforms and networks that interconnect them; and user devices that make use of and act on the available information;
- SUN are required to access and use a specific service through the seamless interconnection among different access technologies, physical objects (e.g., devices and sensors) and logical objects (e.g., content) without being restricted to location;
- SUN are required to support significant interaction among networked human beings and objects to be automatically responsive to human beings, in terms of their presence, activities, preferences and requests.

9 Environmental considerations

The SUN implicitly addresses environmental awareness in terms of context awareness capabilities and needs further study. It is recommended that the details of the environmental impacts be further discussed in other Recommendations related to the SUN.

10 Security considerations

The SUN is recognized as an enhancement of IP-based networks. Thus, it is assumed that security considerations of the SUN, in general, are based on the security of IP-based networks, especially as required to follow the security considerations identified by clauses 7 and 8 of [ITU-T Y.2701].

In addition, the SUN is a short-term realization of FNs. It is therefore assumed that the SUN security considerations should take into account the design goals of FNs, especially identified for "reliability and security" in clause 8.12 of [ITU-T Y.3001].

Bibliography

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