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

Future networks

Smart ubiquitous networks – Context awareness framework

Recommendation ITU-T Y.3043

International Telecommunication Union

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Recommendation ITU-T Y.3043

Smart ubiquitous networks – Context awareness framework

Summary

Recommendation ITU-T Y.3043 describes the framework of context awareness for smart ubiquitous networks (SUN). It also addresses the concept of context awareness as a key capability of SUN. It further specifies requirements based on key characteristics of context awareness. In addition, key functionalities to support context awareness including architectural model and related context awareness mechanisms are also identified. For a better understanding of context awareness for SUN, relevant use cases are described in Appendix II.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y.3043	2013-08-13	13

Keywords

Context awareness, SUN.

FOREWORD

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Smart ubiquitous networks – Context awareness framework

1 Scope

Context awareness has been identified as one of the key capabilities of smart ubiquitous networks (SUN) [ITU-T Y.3041]. This Recommendation describes the framework of context awareness for SUN. This Recommendation covers the following:

- general overview of context awareness for SUN including key characteristics;
- requirements to support context awareness for SUN;
- key functionalities to support context awareness, including the architectural model;
- context awareness mechanisms.

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.2201] Recommendation ITU-T Y.2201 (2009), *Requirements and capabilities for ITU-T NGN*.

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

[ITU-T Y.3041] Recommendation ITU-T Y.3041 (2013), *Smart Ubiquitous Networks – Overview*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 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.

3.1.2 context awareness [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.

3.1.3 smart ubiquitous networks (SUN) [ITU-T Y.3041]: 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, 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.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BGP	Border Gateway Protocol
CA-FE	Context Analysis Functional Entity
CCG-FE	Content Context Gathering Functional Entity
CD-FE	Context Delivery Functional Entity
CF-FE	Context Filtering Functional Entity
CGF	Context Gathering Function
CMAF	Context Management and Analysis Function
CP-FE	Context Prediction Functional Entity
CPU	Central Processing Unit
CR-FE	Context Request Functional Entity
CR&DF	Context Request and Context Delivery Function
DCG-FE	User Device Context Gathering Functional Entity
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technology
IGP	Interior Gateway Protocol
IP	Internet Protocol
IPTV	Internet Protocol Television
NCG-FE	Network Context Gathering Functional Entity
QoE	Quality of Experience
QoS	Quality of Service
OS	Operating System
RFID	Radio Frequency Identification
SCG-FE	Service Context Gathering Functional Entity
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SUN	Smart Ubiquitous Networks
UCG-FE	User Context Gathering Functional Entity
VoD	Video on Demand

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 to this Recommendation.

6 Overview of context awareness for SUN

Context awareness capability of SUN enables networks to dynamically capture context information and monitor the context change in order to be adaptive based on user characteristics and the environment [ITU-T Y.3041]. Context awareness [ITU-T Y.2201] allows a network design for customization and application creation while at the same time ensuring that application operation is compatible not just with the preferences of the individual user but also with the expressed preferences of the enterprise or other collectivity which owns the network.

Context awareness provides the following characteristics:

- Distributed control and management of context sources: ICT systems are distributed and interlinked in a network. These heterogeneous and individual systems may be able to be attached and detached from the ICT system infrastructure at any time. Context awareness can be realized by distributed control and management systems taking into account highly distributed context sources.
- The reduction of complexity: Networks are increasingly becoming larger and more complex to monitor or fully manage in a cost-effective way. Context awareness can contribute towards the reduction of complexity in the management of multiple mechanisms. Sharing context-based information can be realized through dissemination of specific data among different nodes or through cross layer messages inside the same node.
- The incorporation of autonomics: This feature helps communication systems to make the necessary development of extensible context models. These enable the efficient representation of available information, needed for its handling and distributing.

Context refers to location, identities of nearby people and objects, and changes to those objects. The important aspects of context are: where you are, whom you are with and what resources are nearby. The context can be represented as location, identity, environment, time and activity as basic context types for characterizing the situation of a particular context entity.

The context gives the answers to the questions on who (identity), where (location), when (time) and what (activity) for a specific context entity.

NOTE – Appendix I provides detailed information on types of context sources (entities).

7 Requirements to support context awareness for SUN

7.1 General requirements for context awareness

The following are high level requirements of context awareness of SUN:

- As context sources are highly distributed, SUN are required to support distributed control and management systems for context awareness.
- Context gathering:
  - SUN are recommended to provide administrative methods to define context gathering policy.

    NOTE 1 – Gathering policy: context source, gathering method, protocol and time period.
  - SUN are recommended to have the capability to distribute policy to the distributed context sources by use of a pre-defined policy.
  - SUN are required to have the capability to receive context data, understand the protocol in accordance with context source, and extract raw information from data.

    NOTE 2 – Examples of protocol are: IGP, BGP, SNMP, HTTP and proprietary protocols.
- Context analysis:
  - SUN are recommended to have the capability to model the relations between various types of context information.
  - SUN are required to have the capability to transform and filter gathered context information in order to change gathered data to context information.
  - SUN are required to have the capability to interpret context information requiring reasoning and differencing method to change higher level information.
  - SUN are recommended to have the capability to analyse characteristics of pattern of traffic flow, user, social relationship between users, service usage.
- Context prediction:
  - SUN are recommended to have the capability to suggest appropriate preparation by analysing information to upcoming situations.
  - SUN are recommended to have the capability to find network entities of SUN associated with upcoming situations for network control and management.
  - SUN are recommended to have the capability to update the context prediction policy with results of previous predictions to improve accuracy. Therefore, policy or weighting of prediction policy can be changed depending on the situation.
- Context sharing:
  - SUN are required to have a common interface to share abstract context information.
  - SUN are recommended to have a secure mechanism to protect against illegal usage of context information.
  - SUN are recommended to have the capability of a delivery mechanism (e.g., request/response, subscription/notification) to requester.
  - SUN are required to have a context update mechanism to support mobility while switching networks.

7.2 Specific requirements for context delivery

From networking perspective, there are specific requirements regarding context delivery for SUN:

- Scalability: SUN are required to deliver a vast set of contexts to a variety of diverse applications. It is required to be extensible in order to incorporate new contextual information, as the context aware system matures. Furthermore it is required to be adaptive to varying request rates and available network bandwidth.
- Semantic interoperability: SUN are required to define logical constrains such as ontology for more desired matching of the context advertisements and context queries.
- Predictability: With the ability of self-optimization, SUN are required to predict some of the future requests and delivers the contextual information accordingly to the users without getting explicit requests.
- Secure: SUN are required to define policies for access control that is dynamic in nature in order to incorporate changing system trust level. Access control mechanism is required to be autonomous and be interactive to cater for situations in which a user has incomplete knowledge about the existing policies of the system. Furthermore it is required to incorporate encryption mechanism to secure the delivery of context to the appropriate user.
- Real-time: SUN are required to support real time context delivery considering users requests in dynamic networking environment to support ubiquitous capabilities of SUN [ITU-T Y.3041].
- Privacy: Context information raises many privacy concerns if people are tracked by their position or by analysing their preferences and action history. To reduce user fears, it is recommended that the user be always informed about the information that is collected and the security of data transfer.

8 Functional model and architecture to support context awareness in SUN

8.1 Functional model for context awareness

Figure 8-1 shows a high-level functional model to provide context awareness in SUN. This model consists of context sources, context awareness functions and context users.

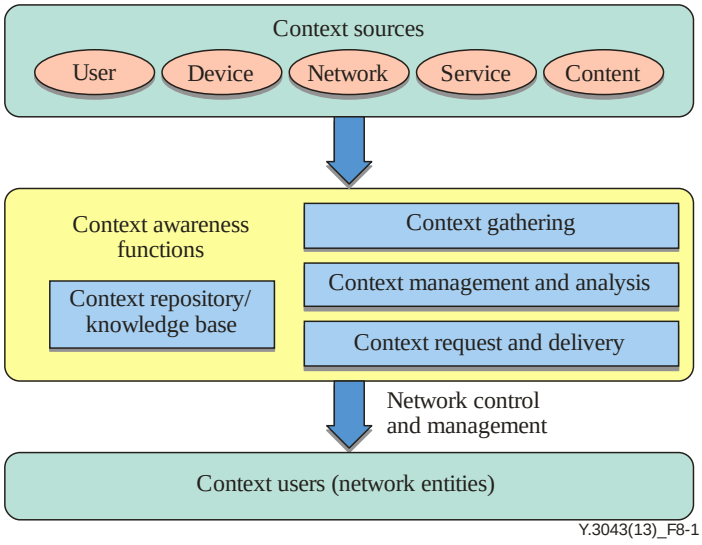

Figure 8-1 – High level functional model for context awareness in SUN

Each block is identified as follows:

- Context source: An entity that provides context information periodically or dynamically.
  - User: A type of context source that can provide user related information.
  - Device: A type of context source that can provide device related information, e.g., smartphone, pad, PC.
  - Network: A type of context source that can provide network related information, e.g., network element such as router, switch.
  - Service: A type of context source that can provide service related information, e.g., content server, service server.
  - Content: A type of context source that can provide content related information, e.g., content type, codec.
- Context awareness functions: An entity that dynamically captures context information, monitors the context change.
  - Context gathering: Collecting context information from distributed entities (e.g., end users, end devices, network entities, time).
  - Context repository and knowledge base: Storing the generated contexts as well as retrieving those contexts whenever necessary, and containing the information for SLA and policies.
  - Context management and analysis: Filtering and statistical analysis of the context information including the prediction of upcoming situations.
  - Context request and delivery: Secure delivery and update of context information to the entities which request the context information.
- Context users: Network elements which have capabilities for network control and management in SUN.

8.2 Functional architecture for context awareness in SUN

For context awareness in SUN, context awareness functions are performed between context sources and context users such as network elements (e.g., related functional entities of routers and switches) in a network. The gathering of information from context sources is analysed and predicted based on context repository and knowledge base for network control and management for context users. Figure 8-2 shows the functional architecture to support context awareness in SUN. This architecture includes detailed functional entities for context gathering, context management and analysis, and context request and delivery, including repositories.

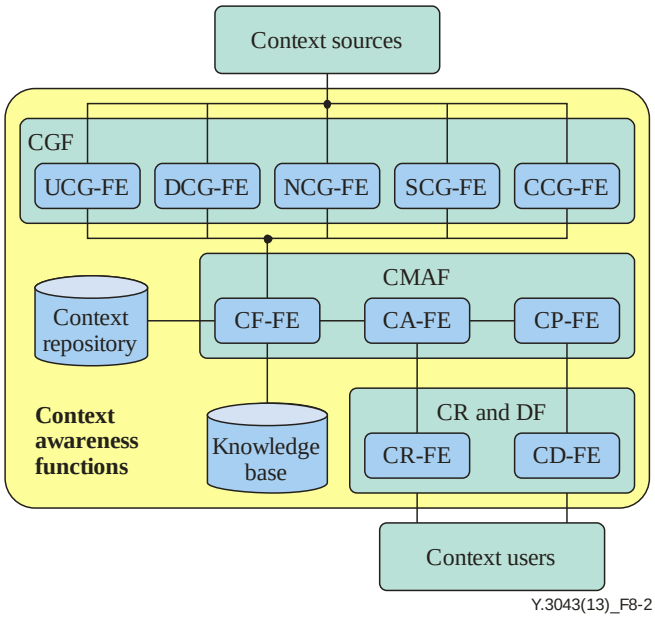

Figure 8-2 – Functional architecture for context awareness

- Context gathering function (CGF): The CGF gathers, dynamically or periodically, updates context information from different context sources (e.g., user, user device, network, service and content) distributed in the network, and sends the data to the CMAF. The CGF includes five functional entities depending on different context sources as follows:
  - User context gathering functional entity (UCG-FE) for gathering user context (e.g., human user identity, personal preferences);
  - User device context gathering functional entity (DCG-FE) for gathering context information from user device context such as environment context (e.g., time, location and physical phenomena);
  - Network context gathering functional entity (NCG-FE) for gathering context information from the network (e.g., resource status of network);
  - Service context gathering functional entity (SCG-FE) for gathering service related context information (e.g., service types);
  - Content context gathering functional entity (CCG-FE) for gathering content related context information (e.g., content types, codec) from content server.
- Context management and analysis function (CMAF): The CMAF performs the filtering of context information, analyses the raw data for context awareness and provides predicted information based on the context repository and the knowledge base.
  - Context filtering functional entity (CF-FE): The CF-FE classifies the raw data gathered from context sources and changes them to the available format used for context analysis, context prediction. In addition the CF-FE sends them to the CA-FE for context analysis or to appropriate repositories for future use.
  - Context analysis functional entity (CA-FE): The CA-FE manipulates raw context information to create more composite and semantically rich information in support of context repository and knowledge base. Then, the created data become meaningful contextual knowledge required by context users.
  - Context prediction functional entity (CP-FE): The CP-FE tries to predict the future context for context users based on the result of context analysis and provides preventive approach to prepare for upcoming situation.

- Context repository: The context repository provides historical data for making decisions based on historical observations. A distributed design for context repository in order to achieve scalability is considered: A centralized context repository in a centralized context awareness system and locally distributed context repositories from various context sources.
- Knowledge base: An information repository that provides a means for information to be collected, organized, shared and utilized for context awareness. It contains a set of data including the information on SLAs and policies, often in the form of rules that describe the knowledge in a logically consistent manner. An ontology can define the structure of stored data – what types of entities are recorded and what their relationships are.
- Context request and context delivery function (CR&DF): The CR&DF collects requests for context information by the network entities and provides the required context information to these entities.
  - Context request functional entity (CR-FE): The CR-FE performs the processing of requests received from functional entities requiring context awareness information in a network and requests the context information to the CA-FE for performing SUN networking capabilities.
  - Context delivery functional entity (CD-FE): The CD-FE reports and shares the predicted context information to related network elements with functional entities to perform networking capabilities for network control and management using context awareness of SUN.

9 Context awareness mechanisms

9.1 Context gathering mechanisms

There are the following mechanisms for context gathering:

- Push mechanism: Context sources periodically push updated context information to the context service.
- Pull mechanism: Context users request context information via polling or on-demand.
- Shared-space mechanism: Context sources periodically publish their information in a place where context users can read it whenever they need.
- Persistence subscription mechanism: Context users subscribe with certain context sources and these sources will provide them with the required context accordingly.

9.2 Decision-making scheme for context prediction

Generally, context information is categorized into static and dynamic:

- static information is quite stable for devices or prefixed by the user, operator or the manufacturer;
- dynamic information can change over time depending on location, system condition or network traffic.

Prediction on dynamic information is difficult since it depends on many other external factors. In addition, it requires study of previous information sets to predict the expected behaviour or results.

For context prediction, Figure 9-1 shows a scheme for decision-making based on context information with both static and dynamic nature of data.

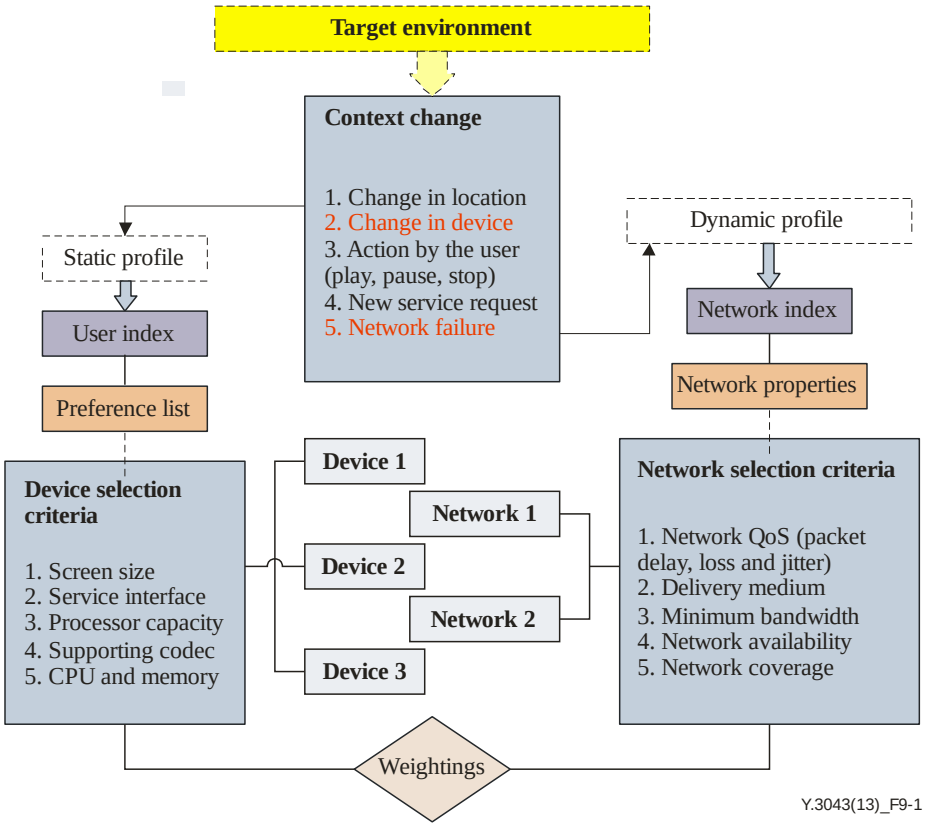

Figure 9-1 – Decision making scheme for context prediction

In Figure 9-1, context information is gathered from the context sources (e.g., sensor around user) and sent to the context prediction functional module (i.e., context predictor) which is located in a home network or an operator network.

Figure 9-1 presents a few context changes like change in device, change in location, subscriber actions, network failures and new service requests coming into the system. There are situations where a user is responsible for the events. In some cases, it can happen due to changes in environment and social interactions.

The context predictor makes decisions based on selection criteria for devices, networks, etc. according to context changes. For a specific case, weightings based on predefined policy are used for adaptive prediction considering dynamic situations.

NOTE – For example, someone watching video content can carry the content over to a mobile device when moving away from the home or work place. Context awareness services are always responsible for delivering a continuous uninterrupted stream to the subscriber. However, implementation always demands correct context information to the context predictor which leads to taking correct decisions. Location change can demand a context predictor to find the best suited network to reach the expected QoE or handover between networks to reach the subscribers. Proper handling of context information immensely improves seamless service continuity. It is important to keep track of subscriber activities and use the environment to achieve better performances of context awareness. Moreover, network supportability is also an important factor for delivering content with minimum delay, jitter and packet loss.

10 Operations model of context awareness in SUN

As shown in Figure 10-1, the centralized context management systems of SUN supports various networking capabilities using context awareness from distributed context sources as follows:

- Context aware content delivery: Delivering related content according to knowledge of the user's current situation by collecting evidence of a context, matching it with other contexts, and searching and integrating the content which is to be delivered.
- Context aware programmability: On demand programming for service configuration according to context and policy information dynamically updated from the underlying network and individual service., In this way, a more scalable and manageable operation including a more efficient and flexible use of the network should be supported.
- Content aware smart resource management: Smart allocation of network resources by exchanging context aware information with other network entities in order to identify changes in the network conditions considering the QoS aspects in various services (including platforms) depending on policies and service scenarios.
- Context aware autonomic network management: Detect, diagnose and repair failures and adapt networks' behaviour through context awareness to monitor or fully manage in a cost-effective way without human intervention.
- Context aware ubiquity (mobility): Dynamically capture and use contextual information about mobile entities and determine the most appropriate connection option at any given time for allowing automatic and seamless switching between different access technologies and services.

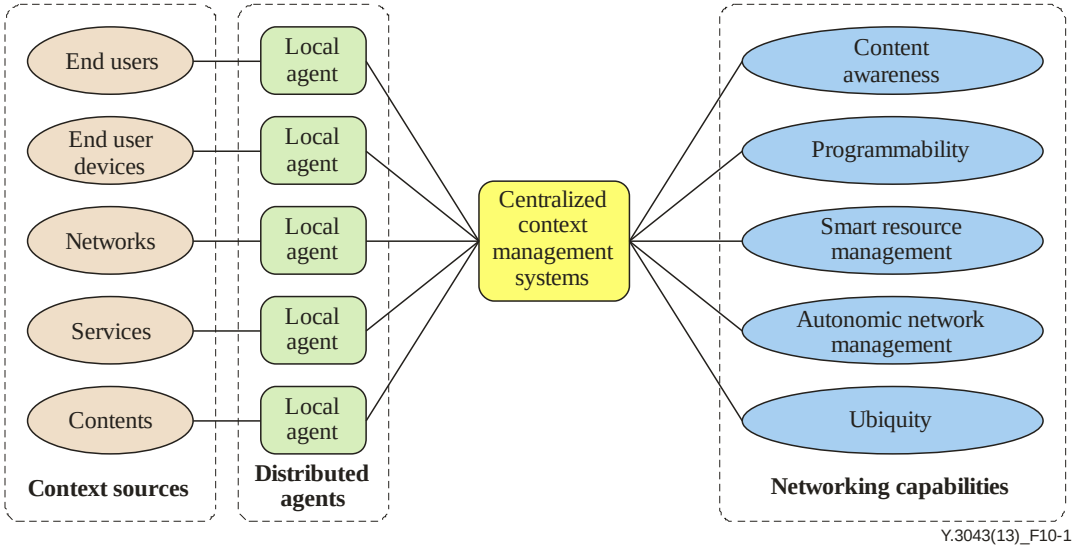

Figure 10-1 – Context awareness to support other networking capabilities

11 Security considerations

SUN are recognized as an enhancement of IP-based networks. Thus, this Recommendation aligns with the security requirements in [ITU-T Y.2701].

Appendix I

Types of context sources (entities) for context awareness

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

Context is any information that can be used to characterize the situation of an entity. An entity (i.e., context source) is a person, place, or object that is considered relevant for the interaction and the communication between a user and an application, including the user and applications themselves.

- User context: Any attributes describing a user's context, e.g., the activity, position, status and so on.
- Device context: Any attributes describing the situation of a device and its environment, e.g., battery status, OS environmental parameters such as available memory, CPU usage and so on.
- Network context: Any information regarding the network, e.g., link state, end-to-end delay and bandwidth, topology information, network types.
- Environmental context: Any information about the environment, e.g., the ambient temperature, light intensity, sound level.
- Flow context: Context in this category express the view of the interaction between user and network. Information could include what type of application is running that produces the flow and state of links or nodes that transport the flow.
- Time context: Time of the day, week, month, season of the year.

Being context aware is the ability of an entity to be aware of the current circumstances and be aware of relevant information that may influence any decision and behavioural change based on the context, whatever it might be.

In practice, entities with context awareness are divided into two groups:

- Proactive: Those entities providing proactive context awareness, use context information proactively to react on changes, e.g., by changing parameters and configuration to fit into the new situation or notifying a user of something.
- Reactive: Those entities reactively using context information typically need to know the current situation to make a decision here and now. An example is context aware service discovery.

Appendix II

Applications and use case of context awareness

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

II.1 Applications of context awareness

II.1.1 Context aware services

Typically, a context aware service uses context information to:

- automatically deploy services for a user or to control an environment;
- associate context information with other information, allowing subsequent access to this based on "contextual" search criteria (e.g., "find all information relevant to this place");
- personalize modes of interaction between the user and the service;
- select services relevant to the user in a given environment or situation (context aware service discovery and provisioning).

II.1.2 Context aware content delivery

Context aware content delivery can be the bridge between knowing the mobile user's current situation and delivering related content to that situation. It can be an ideal tool to deliver content in a useful and focused way for content providers. Fundamentally, the process can be defined as collecting evidence of a context, matching it with other contexts in the context space, and searching and integrating the content, which is to be delivered. This is how the linking between context and content items/info packages should be done in order to put content into context.

II.1.3 Context aware security

Context aware security delivers deeper insight, more effective security and improved operational efficiency through the use of high-level policies defined and enforced based on a user's identity, location, and time of access; the type of content being accessed; and the type of device and application accessing the content.

II.1.4 Context aware QoS

Context aware QoS considers the QoS aspects of the awareness in various service platforms depending on policies and service scenarios. For example, the QoS offered by the communication network infrastructure is likely to change and a service platform must respond. The service platform should incorporate a user's context information when mapping end-user QoS to communication network QoS.

II.1.5 Context aware mobility

Context aware mobility is the ability to dynamically capture and use contextual information about mobile assets. Contextual information can be automatically collected using the wireless connectivity of the asset (e.g., laptops or smart phones) or for assets that do not have intrinsic wireless, by attaching RFID tags. In addition to identity information, the context data collected may include the date, the time of the day, its physical location, the surrounding temperature, humidity or pressure, whether the asset is in motion or not, and any other information relevant to the business process.

Through the collaboration of context aware systems that determines the most appropriate connection option at any given time, context aware mobility allows automatic and seamless switching between different access technologies and services in smart ubiquitous environment.

II.1.6 Context aware energy conservation

It is very important that the higher levels of the system be actively involved to ensure that the available energy is conserved and utilized in the most efficient way. One of the major challenges of pervasive computing is to exploit the changing environment with a new class of applications that are aware of the context in which they run. A context aware system can examine the computing environment and react to changes to the environment.

Context information can be used to reduce energy consumption of the device. Contexts such as location, network connectivity, date and time, remaining energy, local and remote resources available can be used by the higher levels of the system for efficient utilization of energy. The system should also be able to adapt to changes in these contexts.

II.2 A use case of context awareness – context aware content delivery services

The context aware content delivery service first captures user context, including that for the user's device, analyses and interprets this, retrieves the content from the content servers that the user needs based on the interpretation, converts the medium for the content into one adapted to the capabilities of the user device if necessary, and provides the user device with the converted content.

The following mechanism is necessary for content delivery services using context awareness.

Content conversion and its provision: The content that is delivered to the user should be converted into a form that is adapted to the capabilities of the receiver's device and the functions to display it.

Context awareness provides good backend support for existing IPTV services. It makes services more user-friendly and adaptable on user preference. In real world, the context aware factors, which constitute context awareness, change rapidly and therefore the factors tend to become subjective and domain specific.

As an example, IPTV services in home environment which is subjected to relatively low rate of change in events are considered. Context aware IPTV service is supported by the factors like location, time, device capabilities and network characteristics. Location-based information can be classified into two categories as indoor and outdoor. Indoor environment is an extension to smart home concept where all context information is forwarded to a local context manager at home network or distributed managers in the operator network. Local context managers are not always smart enough to take crucial decisions related to flow control, QoS management, minimizing delay and utilization of resource. Strategically, network operator locates global context managers closed to access networks to minimize the delay response. The concept of smart home provides a good support for context aware services in the indoor environment. In a home environment, context information is gathered with sensors which are capable of detecting voice, motion and environmental factors like temperature, humidity and brightness. RFID is another common technique used for capturing context due to compactness and low manufacturing cost.

Time shift TV is one step ahead of IPTV, as it supports trick mode operations like forward, backward, pause and play functionalities over broadcast TV. In other words, time shift TV service offers subscriber freedom in time domain by allowing them to watch preferable media contents which are already broadcasted over linear TV. This service allows users to customize the normal broadcast TV service according to their preferences. Such services are supported in both indoor and outdoor environments. Assume a person watching normal broadcast TV in his living room wants to go to the dining room and continue watching the same content on another device from the point of interruption. Time shift TV supports such a scenario while allowing their subscribers to 'pause', 'play', 'forward', 'backward' or 'stop' the broadcast stream at any time and resume from the place where he/she stopped streaming content regardless of the device or location.

In this use case, some useful contexts are considered as follows:

- memory size;
- computing power;
- battery lifetime and energy consumption;
- screen size;
- available bandwidth;
- requested content type.

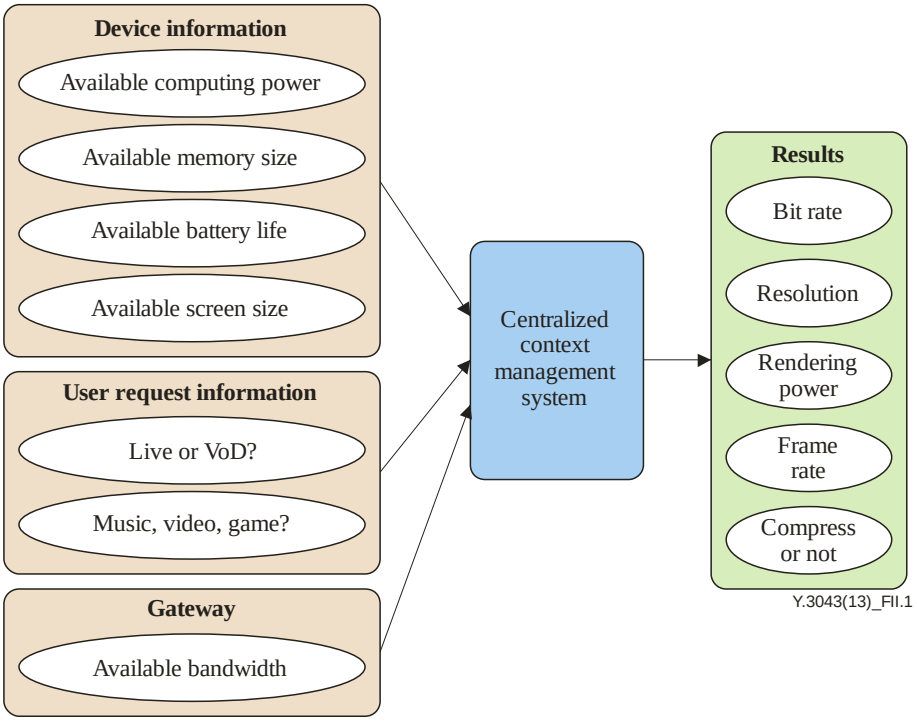

Figure II.1 – Example of context information for context aware content delivery

With considering above contexts, a context-aware system can provide some relevant information and/or services for users. For example a context-aware system needs to decide about ability of a device for "rendering". There are three options: full rendering in the device, full rendering in the cloud, half in the device/half in the cloud. Based on evaluating different contexts, a context-aware system can make an appropriate decision. If computing power and memory size of the device are qualify enough and there is no energy problem and also bandwidth not available, may be full rendering in device be best choice.

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