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

Future networks

Smart ubiquitous networks – Content awareness framework

Recommendation ITU-T Y.3044

International Telecommunication Union

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Recommendation ITU-T Y.3044

Smart ubiquitous networks – Content awareness framework

Summary

Recommendation ITU-T Y.3044 describes a framework for the content awareness feature of smart ubiquitous networks (SUN). The content awareness feature of SUN considers enhanced capabilities to enable networks to optimally and efficiently handle the content. This Recommendation describes the concept, functional requirements and functional model of content awareness of SUN.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y.3044	2013-08-13	13

Keywords

Content awareness, SUN.

FOREWORD

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

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

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

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Smart ubiquitous networks – Content awareness framework

1 Scope

This Recommendation describes a framework for content awareness feature of smart ubiquitous networks (SUN). The content awareness feature of SUN considers enhanced capabilities to enable networks to optimally and efficiently handle the content.

This Recommendation covers the following:

- the concept of content awareness;
- functional requirements to support the content awareness feature;
- the functional model for content awareness of SUN.

While the high-level requirements of the content awareness feature of SUN are covered in [ITU-T Y.3041], this Recommendation specifies the detailed functional requirements to realize the capability of content awareness of SUN.

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.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 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.

3.1.3 context awareness [b-ITU-T Y.2201]: Context-awareness is the 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 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:

AAA	Authentication, Authorization and Accounting
CDN	Content Delivery Network
CP	Content Provider
DDoS	Distributed Denial of Service
DNS	Domain Name System
FE	Functional Entity
HD	High Definition
HTTP	Hyper Text Transfer Protocol
ID	Identifier
IP	Internet Protocol
OSPF	Open Shortest Path First
QoS	Quality of Service
SD	Standard Definition
SUN	Smart Ubiquitous Networks
URL	Uniform Resource Locator

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

Smart ubiquitous networks (SUN) are IP-based packet networks that can provide transport and delivery of a wide range of existing and emerging services to people and things [ITU-T Y.3041]. The services provided by the SUN cover aspects such as control, processing and storage.

Content awareness is a key feature of SUN to support an optimized content delivery service. Content awareness is an ability to identify, retrieve and deliver contents efficiently based on the content-related information considering location and/or user. Using this feature, SUN identifies content by its name or other relevant information (i.e., metadata) to deliver and retrieve the content efficiently. It can prevent the duplicated transmission of the same contents by content routing and delivery with the content name. Content caching (i.e., in-network caching) and delivery in the node close to users can provide a high-quality video streaming service for surges of content requests.

The content awareness feature of SUN provides the following capabilities:

- **Content discovery**: Discover the content location for content storages or caches by content name (i.e., name-based content routing) rather than its location-dependent identifier (e.g., IP address). The name-based content routing allows the end users to access content by the content name regardless of the change of the location of content as well as of the end users. The content or content location can be dynamically determined according to the content metadata or the location of the end users for optimized content delivery. The name-based content routing also prevents content sources from being damaged by attack such as DDoS because it hides the network locations (e.g., IP addresses) of content sources susceptible to exterior ill-intentioned threats.
- **Content caching**: Stores and caches the content in the storage of SUN nodes. It can reduce transfer delays and network costs due to large distances between content sources and end users. Based on the content caches, SUN provide end users content proximity information such network topology and regional network cost for content delivery. Locality of the content provision gives content provider the benefit of saving costs and proximity-based content delivery gives the end users a better content delivery QoS.
- **Content distribution**: Dynamically distribute content, which is in caches and storages in the network according to traffic load, usage and user location, taking QoS and traffic optimization into account. The popular content may be distributed to the SUN nodes which are close to end users. Multiple requests for the same content from different end users can be served together along a single multicast spanning tree. This results in efficient content delivery and traffic optimization.

These capabilities for content awareness are performed by dedicated SUN nodes, i.e., content nodes, which are deployed at strategic locations in the network. They are connected by logical links and form a logical network (i.e., content overlay network) over which content routing and delivery are provided. Published content over the content overlay network is to be identified with mappings to the specific locations of the overlaid network. For content awareness capabilities, the content can be discovered, cached, and distributed as file-level or chunk-level in SUN.

7 Functional requirements

Functional requirements for content awareness are summarized as follows:

7.1 Content discovery

- SUN are required to provide the capability to identify content by name or ID.

  NOTE 1 – The content name or ID can be used to identify content at the file level and/or chunk level.

- The content name or ID is required to be unique in a global scale or in a local scale with mapping mechanisms.
- SUN are required to provide the capability of content namespace management.
- SUN are required to provide the capability to register and retrieve the content metadata which describes the content properties such as content creator/provider, date of creation and content location, etc.

  NOTE 2 – The content metadata can be maintained either centralized or distributed.

- SUN are required to provide the capability to search the content using content name or content ID.
- SUN are required to provide the capability to determine the location of the content when it is published in the network.
- SUN are required to provide the capability to maintain the mapping relation between content names and content locations in the network.
- SUN are recommended to provide the capability to search the content and provide a content delivery service based on content metadata.
- SUN are recommended to provide the capability to select the closest content location to the end user by the name of the content.
- SUN are recommended to provide the capability to select the content location taking into account network state, network resource availability, and network congestions.
- SUN are recommended to provide the capability to optimize the network traffic.

  NOTE 3 – Using this capability, the content routing path can be adapted to localize the traffic.

7.2 Content caching

- SUN are required to provide the capability to store/cache the content in its local storage of content nodes.
- SUN are required to provide the capability to apply different policies when replacing the content in a content cache.
- SUN are required to provide the capability of publication of the content from content providers.
- SUN are required to provide the capability to register and retrieve the stored content for content providers and network providers.

  NOTE 1 – Using this capability, the content providers or network providers may add or remove content to/from the SUN.

- SUN are required to provide the capability to cache a frequently requested content in a network node close to the end user.

  NOTE 2 – The caching policy is determined by the service provider.

- SUN are required to provide the capability to retrieve the cached content when the requested content name matches to the cached content name.

- SUN are required to provide the capability to inform about the location of the content when it is queried by the content name.
- SUN are required to provide the capability to manage a content overlay network comprising content nodes for content routing and delivery.

7.3 Content distribution

- SUN are recommended to provide the capability to distribute the cached content to other caches at different locations.

  NOTE – Using this capability, the content may be dynamically located closer to end users.
- SUN are recommended to provide the capability to constitute a multicast spanning tree when the same content is requested multiple times from different locations.
- SUN are recommended to provide the capability to coordinate an adaptive bit-rate streaming technique with the content name.
- SUN are recommended to provide the capability to support a chunk-based content delivery method.

8 Functional model of content awareness

8.1 Overview of functional model

Based on the aforementioned capabilities and functional requirements, the high-level functional model for content awareness in SUN are as shown in Figure 8-1.

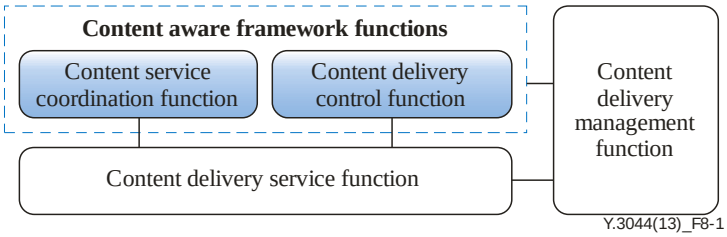

Figure 8-1 – Functional model for content awareness in SUN

The functional model for content awareness consists of four distinct functions, content service coordination function, content delivery control function, content delivery service function and content delivery management function.

The content service coordination function and the content delivery control function can be classified as content-aware framework functions. They provide an optimal content aware environment for the content delivery service function, which is providing the requested content to the end user using a name-based content delivery mechanism. The content delivery management function provides the management interface of content delivery resources including service and user profiles, performance, usage data and inventory in the management plane.

Accordingly, the content-aware framework function focuses on the relevant issues of content awareness which are within the scope of this Recommendation.

The content service coordination function performs the interactive operations between the service provider and the end users of SUN. It redirects a content request from an end user to the optimal content node which is supposed to offer the best quality of service to the user. It also helps the content provider to publish their content into the optimal content node in SUN along with content identification process.

The content delivery control function builds of content overlay network for providing a name-based optimal content delivery environments to the service provider. It determines an optimal content node to serve the optimized selection process based on proximity information. It decides for a routing node or a forwarding path to handle the content request message.

The content service coordination function comprises the content publication functional entity and the service request routing functional entity. The content delivery control function comprises the service optimization functional entity and the content name resolution functional entity. The content-aware framework functions are shown in Figure 8-2.

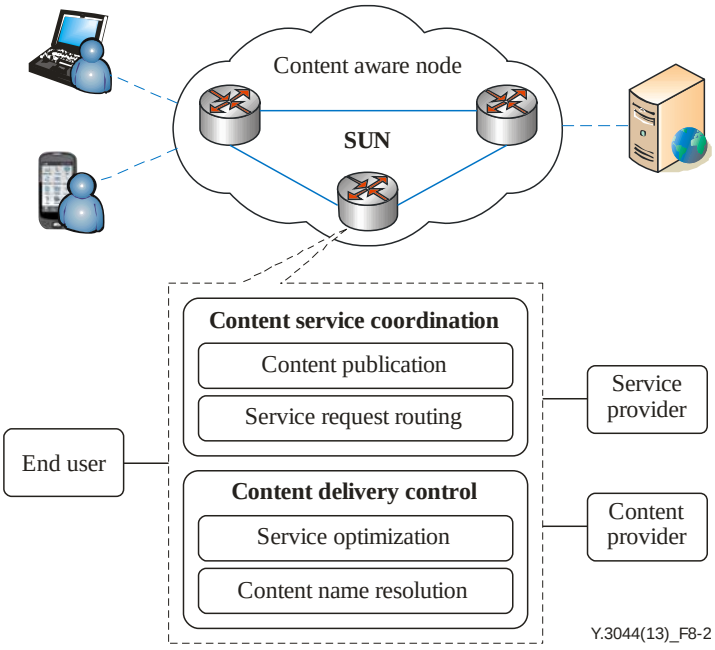

Figure 8-2 – Content-aware framework functions

8.2 Content service coordination function

The content service coordination function is intended to help content providers publish their content in the network. It generates content IDs for the content and identifies the optimal content node where the content will be published. Additional information such as URLs of the content repository and metadata of the content from the content provider are provided to the selected content node as well. For completion of the content publication process, the content service coordination function sends the mapping information between content ID and published content node address to the content name resolution FE in the content delivery control function.

When receiving a content request from an end user via a content service provider's portal, the content service coordination function routes the end user's request to the optimal content node where the service requesting end user will be served. The redirection procedure of the service request to the optimal content node as decided by the service optimization FE in content delivery control function could be implemented using the HTTP [b-IETF RFC 2616] redirection or the DNS-based routing mechanism, etc. The content service coordination function is shown in Figure 8-3.

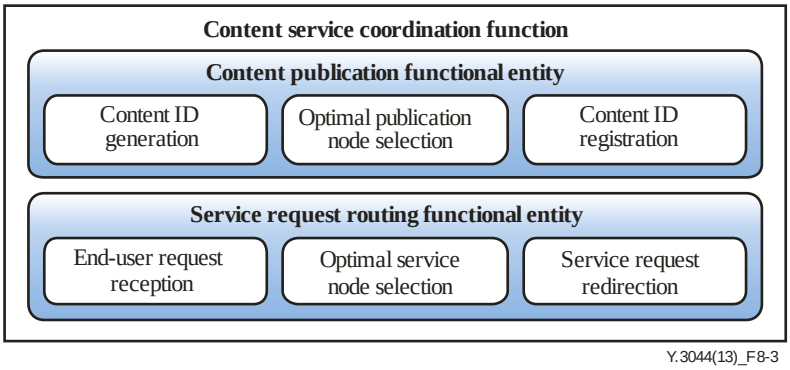

Figure 8-3 – Structure of content service coordination function

The content publication FE carries out the following roles:

– generation of content IDs for the publication requests (URL + metadata) from content providers;

– extracting the optimal content node where the content will be published;

– registration of the published content to the content name resolution function.

The service request routing FE carries out the following roles:

– interfacing end users with the portal of content providers;

– identifies the optimal content node where the service requesting user will be served;

– service request redirection to the selected content node using appropriate mechanisms (e.g., HTTP redirection or DNS-based routing mechanism, etc.).

8.3 Content delivery control function

The content delivery control function consists of two distinct FEs for service optimization and content name resolution. The service optimization FE organizes a content overlay network. To locate the content properly as requested by the end user, the service optimization FE determines the next hop to forward the content request packet coming from the previous node. Another key role of this FE is the selection of the optimal content node based on proximity, network status and service availabilities for requesting routing from the content service coordination function or an internal selection of the next hop node when multiple paths to the destination content node have been found in the content name resolution FE.

Maintaining the relation between a content ID and a content location is the first step of the name-based content routing mechanism. In the publishing stage, the content service coordination function creates a content ID and selects the optimal content node to publish the content. After that, the content service coordination function sends content ID and content location to the content delivery control function for registration. The content name resolution FE carries out the registration, deregistration and update of the content ID along with its locator. The content name resolution function responds to the queries from the content delivery service function. The query of the content location with content ID occurs when the content delivery service system wants to know the interface to forward the content request packet from the previous content node or end user in the content overlay network.

The content delivery control function is shown in Figure 8-4.

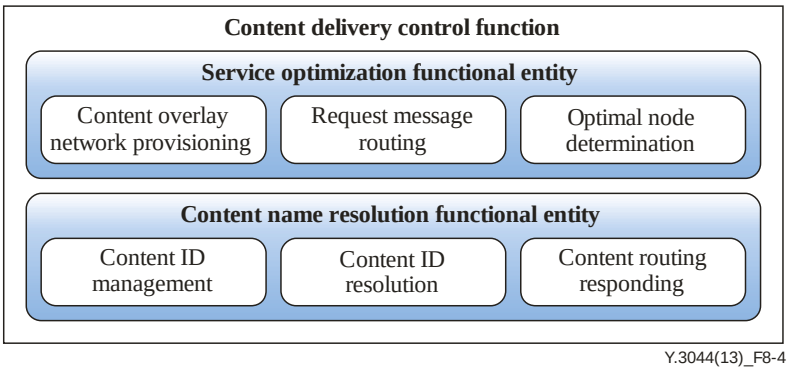

Figure 8-4 – Structure of content delivery control function

The service optimization FE carries out the following roles:

– provisioning of content overlay networks;

– determining locators for routing or forwarding the content request message;

– selecting the optimal content node based on proximity, network topology and service availabilities.

The content name resolution FE carries out the following roles:

– registering/deregistering/updating of content ID along with its locators;

– resolution of one-to-many mapping with content ID and content locators;

– responding ID-location query from the content node.

9 Environmental considerations

The content awareness framework of SUN enable optimized content delivery service by identifying content by its name or metadata to distribute and retrieve the content and caching the content in the in-network content storage close to users. These capabilities prevent duplicated transmission of the same content and shorten the content delivery path. Consequently, energy consumption of the network elements can be reduced as the number of network elements which participate in the content delivery operations decreases.

10 Security considerations

In traditional content delivery services, AAA (authentication, authorization and accounting) is performed by content providers to guarantee secure content delivery in an end-to-end manner. In content awareness framework of SUN, however, content can be cached in-network storages so that the end users can retrieve the content from the intermediate network storages rather than original content providers. This may cause a security hole with the traditional AAA in an end-to-end manner. Thus, additional security procedures are required for content delivery between end users and network caches; and between network caches and content providers.

11 Accessibility considerations

People with disabilities or people with special needs require easy use of content services. The content service includes discovery, access, and consumption of contents through the network. The content awareness feature of SUN does not need to restrict people in their ability to use the content service of SUN. Capability of content handling by the name or identifier can provide an enhanced accessibility feature for disabled people. Further accessibility considerations are required to design content aware content delivery services for SUN.

Appendix I

Examples of content descriptors

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

I.1 Content descriptor

Examples of content descriptors are shown in Table I.1.

Table I.1 – Example of content descriptor

Content descriptor	Description	Example
ContentID	A unique identifier of a content consisting of a content name and a content id	
Content creator	A unique identifier of the content creator	
Content provider	A unique identifier of the content provider or the content aggregator	
Origin file location	Location information (sever IP) of content origin	
Copied file location	Location information(server IP) of the copied content	
Video resolution	Video resolution type	1080i, 1080p, 720p
Service type	Full HD, HD and SD	

When content is identified and delivered by chunk level, ContentID can be a unique identifier of the chunk as a byte range of content name and indicate a set of multiple chunk IDs.

Appendix II

Example mechanisms for content awareness framework

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

II.1 Content publication

A content provider (CP) expresses to the service provider its intention to publish content by sending a URL and metadata. The URL points to the origin server for accessing the content and metadata describing the content. The metadata include information such as the name of content, a description, the total size of the content, CP identifier, etc. From the metadata, the service router generates a routing identifier.

Then the service router sends the publication result (the identifier and the URL) to the SUN node. The recipient SUN node saves the mapping between the identifier and the URL, and sends a registration message to a registry. The registration message contains the routing identifier and the address of the SUN node. The registry maintains the records which map an identifier to its actual locations.

It should be noted that all SUN nodes can potentially play the role of reverse proxy.

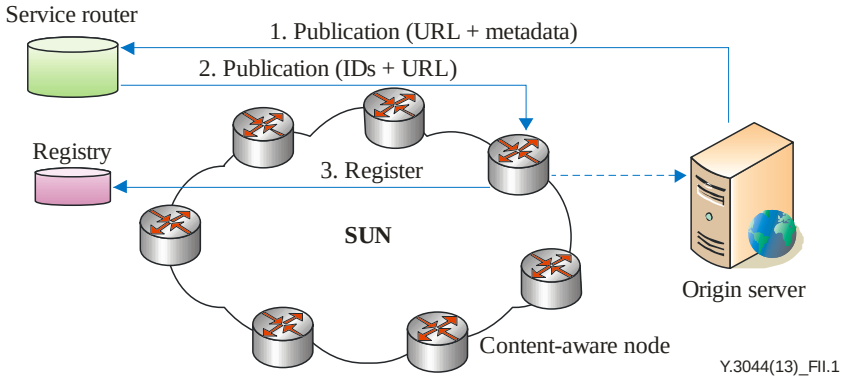

Figure II.1 – Content publication in SUN

II.2 Request routing

The service router is the first entity that receives a HTTP GET request from end users. In the content delivery network designed over SUN, the service router selects a content node for redirecting the HTTP GET request.

The service router converts a file name within a URL into a sequence of identifiers. To handle the conversion, the service router should manage or interact with a database that maintains the mapping between information metadata and identifiers. The metadata should contain the description of the content sufficient for it to be uniquely mapped to a sequence of identifiers. The original HTTP GET request and its URL are modified in the result of the conversion, and are redirected to the most optimal content node, e.g., in terms of proximity, which is able to service the sequence of identifiers.

Because of the aggregate information relationship, the conversion result should be 'a sequence of' identifiers. If a hierarchical naming structure is used, this sequence of identifiers can be converted into a single identifier. However, the hierarchical naming structure makes it hard to predict the length of the identifier. Therefore, it is more desirable to separate an identifier into a routing identifier and its sub-identifiers.

Normally, the routing identifier uniquely identifies a single publication of information in the SUN. It is mainly used to route the content request packets to the destinations. The sub-identifiers of the identifier uniquely identify one component of the publication.

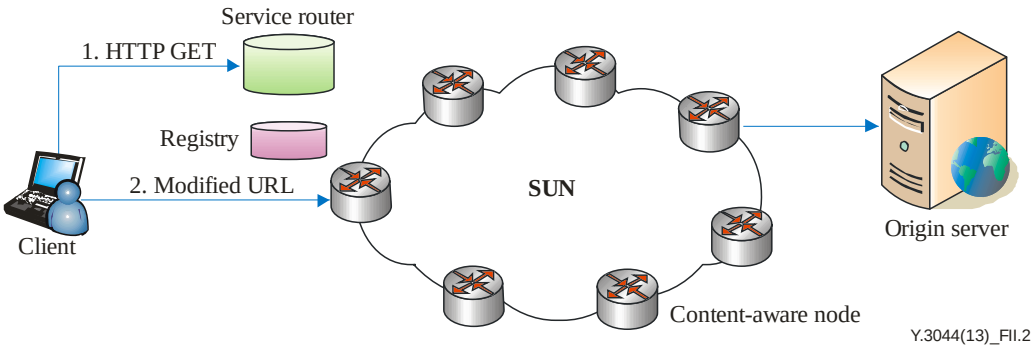

Figure II.2 – Request routing in SUN

II.3 Content routing

II.3.1 Registry-based content routing

A consumer of information issues a 'content request' on the information and a producer of the information sends a response to the content request. However, the network requires a proactive and *a priori* deployment of the FIB entries to forward the content request packets. It takes a rather different approach of 'querying' the location of information before sending content requests, and relying on IP FIB entries to forward the content requests to the destination.

First, a HTTP GET request for content is delivered to the service router, via the traditional CDN request routing mechanism. On receiving the request, the service router looks up its database and converts the HTTP GET request to include the identifier of the content. Then, the modified request is redirected to the nearby content node and its streamer. To service the request, the streamer looks up the requested file in the virtual file system. The file system converts the file lookup to content requests and submits the content requests into the network.

To send a content request for X (e.g., a content name), a node first queries its location at the registry (Figure II.3). If content X is published in the network, the registry replies with its address y. The address y is embedded into the content request packet to be used as a routing hint by all intermediate SUN nodes on the path to the destination of the content request. As all content nodes are OSPF capable, each node is able to calculate the address of the next-hop by consulting the OSPF FIB entries. Before forwarding the content request packet, each content node replaces the destination IP address of the packet with the next-hop address.

On receiving a content request, each content node checks if it has the requested content X. If there is a cached chunk of X, it is replied. If not, the node forwards the content request to the next-hop content node. If the content request reaches the final destination y, the destination node looks for X in its file system. If X is not in its file system, the node tries to download the content from the origin server by consulting the reverse proxy records. On downloading the content, the content node sends a reply (data packet) to the content request packet. The data packet forwarding scheme is basically the same as the content request packet forwarding scheme.

The information-routing scheme described in this appendix is interoperable with traditional IP routers because each content node switches the destination IP address field in the packet header to the address of next-hop content node. To the legacy IP routers, all the SUN packets are just plain IP packets. Therefore, SUN enables legacy IP routers to be incrementally replaced with content nodes.

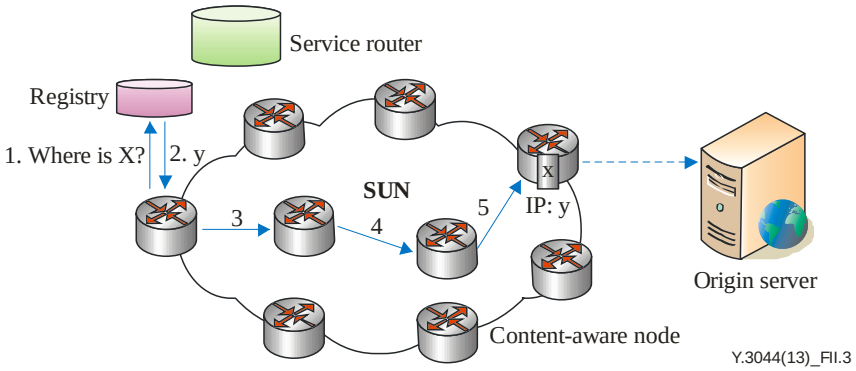

Figure II.3 – Registry-based content routing in SUN

II.3.2 Indexing-based content routing

Content routing should be carried out in a fast and efficient way. Routing look-up is done by the longest prefix matching on content name or contentID. A content-aware node provides its own content descriptor and route information to the target content by having a routing table for content-aware nodes. Since the network scales as the number of contents increases, fast retrieval is the most important factor of content routing.

There are several ways to reduce the content searching time in a large-scale network.

Previous routing path caching in root node:

The network would have the representative (root) node of regional area to memorize the previous routing path during a short period. The root node memorizes the previous routing paths of requested content in its memory or temporary buffer. A content-aware node first asks the root node and then retrieves the routing table by its original mechanism. If the root node has the routing path for the content, content retrieval time will be shortened by reducing routing look-up time.

Indexing nodes locating in the network:

Large content-aware networks have a management domain in the network and this domain has several index nodes having aggregated content metadata as mentioned in content descriptor management. Index nodes have an aggregation database of content metadata of sub-domain nodes. Index nodes are determined by the number of nodes of the network and are added as the network scales. If a content-aware node searches the content through index nodes, it reduces the number of routing look-up hops by jumping intermediate nodes between index nodes.

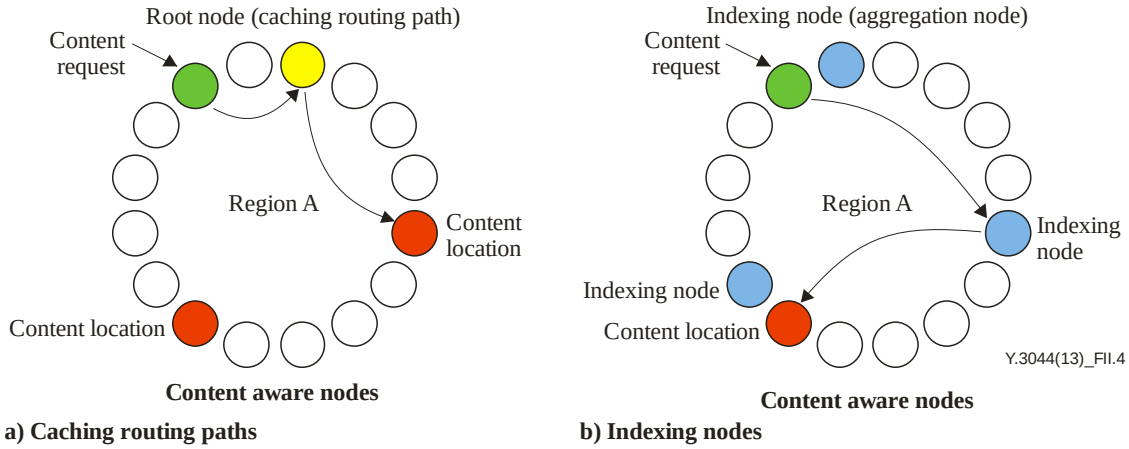

Figure II.4 – Indexing-based content routing in SUN

II.4 Content distribution and caching

Content caching identifies a capability to store/cache the content in the local storages of content aware nodes. Content caching is a very important feature to provide content delivery service to end users. Prepositioning the contents to edge network caches makes it possible to provide large-size and high-quality content services. Especially, live contents need an intelligent distribution and caching policy and sophisticated load balancing mechanism for unexpected heavy request traffic. This capability includes caching and policy mechanisms to manage the cache. These are major considerations for manipulating the content caching mechanism among content aware nodes.

1) Prepositioning content to the edge:

   Popular and live contents will be prepositioning in a near node according to the prediction of the number of end users. Figure II.5 shows the content distribution and caching from the content origin server thru the root node to the usual nodes. The root node is the representative node of a regional area. The number of cached nodes is dependent on the number of end users.

2) Load balancing the unexpected heavy request traffic:

   Live contents are serviced through the regional root node and the root node has the task to preposition the content to the nodes nearest to end users. Sometimes, there is unexpected heavy request traffic and all content aware nodes exceed the threshold of resource utilization. When the resources of region B are fully utilized, the resources of region A will be used in a load balancing process. If many end users of region B make another request during a service session, one of the service nodes exceeds its threshold, resulting in deteriorated service quality. This situation is reported to the platform and the platform sends the message to an available node in region A. This new available node in region A establishes a session with the end user of the nearly saturated node of region B and starts to offer continual service to the end user, and the nearly saturated node of region B quits the session with the end user. It is an example of a seamlessly changing service node during the session to load balance the utilization of nodes.

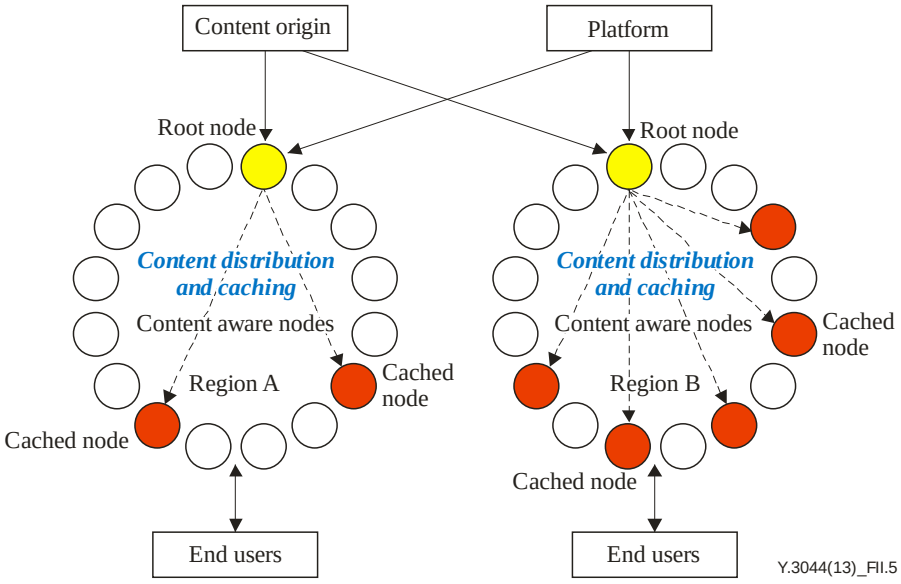

Figure II.5 – Mechanisms for content distribution and caching

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