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

Future networks

Smart ubiquitous networks – Functional architecture of content delivery

Recommendation ITU-T Y.3045

International Telecommunication Union

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Recommendation ITU-T Y.3045

Smart ubiquitous networks – Functional architecture of content delivery

Summary

Recommendation ITU-T Y.3045 specifies the functional architecture of content delivery in smart ubiquitous networks (SUN) by describing the relevant capabilities, functions, operations and informational flows.

The features of SUN content delivery are name-based content routing, in-network content caching, content delivery optimization, and dynamic content routing adaptive to context information whose principles are content awareness and context awareness as defined in Recommendations ITU-T Y.3044 and ITU-T Y.3043, respectively.

The content delivery in SUN consists of content publication, content service provisioning, content routing and content caching as capabilities to support the aforementioned features.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3045	2014-01-13	13	11.1002/1000/12077-en

Keywords

Content delivery, SUN.

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1 Scope

This Recommendation provides the functional architecture of content delivery in smart ubiquitous networks (SUN) by specifying the relevant capabilities, functions, operations and informational flows. The capabilities of content delivery in SUN are identified considering content-awareness [ITU-T Y.3044] and context-awareness [ITU-T Y.3043] capabilities 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*.

[ITU-T Y.3043] Recommendation ITU-T Y.3043 (2013), *Smart ubiquitous networks – Context awareness framework.*

[ITU-T Y.3044] Recommendation ITU-T Y.3044 (2013), *Smart ubiquitous networks – Content awareness framework.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 content awareness [ITU-T Y.3044], clause 6: An ability to identify, retrieve and deliver contents efficiently based on the content-related information considering location and/or user.

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 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 effect 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

CN-FE Content Name resolution Functional Entity

CP-FE Content Publication Functional Entity

CR-FE Content Routing & caching Functional Entity

CS-FE Content Service Functional Entity

CT-FE Content Transfer Functional Entity

DNS Domain Name Server

FE Functional Entity

HTTP Hyper Text Transfer Protocol

SO-FE Service node Optimization Functional Entity

SUN Smart Ubiquitous Networks

URL Uniform Resource Locator

5 Conventions

None.

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]. While the services provided by the SUN can cover aspects such as control, processing and storage, one of the essential services is content delivery.

The SUN content delivery mainly focuses on the how to deliver the content efficiently in a content and context aware manner. In other words, the content delivery exploits context information to adapt to the dynamic user characteristics and environment, and content aware capabilities of the network to provide personalized and optimized services. The details about context information and content aware capabilities are described in the context awareness framework [ITU-T Y.3043] and the content awareness framework [ITU-T Y.3044], respectively.

Based on the aforementioned characteristics, the SUN content delivery provides the following high-level features:

– Name-based content routing for content location discovery.

– In-network content caching for intermediate content storages.

– Content delivery optimization using in-network caches and path control.

– Dynamic content routing adaptive to context information.

In this Recommendation SUN content delivery is described in detail. First, it provides several capabilities for content delivery among content providers and end users over SUN based on content awareness functions and context awareness functions. Second, it covers the details about the

functional architecture with several functional entities. Third, it provides the operations and informational flows among the functional entities to support the SUN content delivery functions.

7 Features and capabilities for SUN content delivery

SUN content delivery exploits the content-awareness [ITU-T Y.3044] and context-awareness [ITU-T Y.3043] capabilities of SUN to provide enhanced content delivery. The SUN content-awareness capability provides an ability to identify, retrieve and deliver contents efficiently based on the content-related information. The SUN context-awareness capability provides management and monitoring of context information and its changes for adaptive network operations. With these two capabilities, SUN content delivery provides four features: name-based content routing, in-network content caching, content delivery optimization and content routing adaptation.

– Name-based content routing:
  - Routing the content based on its name such as the content ID rather than its location
  - Information about content (or metadata) can be used for content routing along with the content ID.

– In-network content caching:
  - Caching the requested content in the network to reduce transfer delay and duplication for delivering the same content from content sources
  - The unit of caching can be a chunk of the whole content distributed over the network by an appropriate caching policy.

– Content delivery optimization:
  - Routing the content request by an end user according to the proximity, network status, resource condition and context information
  - Cached content in the network can be reused for delivery at additional requests for the same content.

– Dynamic content routing adaptive to context information:
  - Dynamic changes of content routing paths or content storages (including content caches) according to the changes of the user and network context (e.g., network failure, network overload, use location, etc.).

    NOTE – The detailed use cases for context-aware content delivery are described in Appendix I.

In order to provide these features, SUN content delivery functions provide four capabilities, as depicted in Figure 7-1. These capabilities are realized by distributed service nodes in SUN, which are capable of SUN content delivery functions.

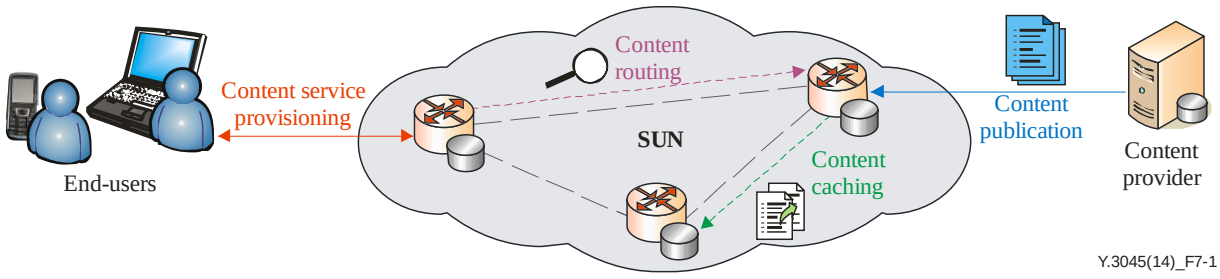

Figure 7-1 – Capabilities of SUN content delivery

– Content publication:

  Content publication capability handles the request of content providers for content registration to the network with detailed content information including the location of

content sources. Based on this content information, it downloads the content from the content source to store the content in the storages of the network.

– Content caching:

Content caching capability distributes the content to the content caches of service nodes to optimize the content traffic by reducing the distances between the content sources and end users. The content is dynamically distributed to the multiple caches along the content routing paths.

– Content service provisioning:

Content service provisioning capability handles content requests from end users by selecting appropriate content with the given content ID according to the user context, and discovering the optimal content location that can transfer the content to the end user efficiently in terms of location and traffic optimization.

– Content routing:

Content routing capability discovers the content location based on the content locators determined by the content ID. The target content location fetches the content and transfers it to the requesting service nodes.

8 Functional architecture

The functional architecture of SUN content delivery is depicted in Figure 8-1.

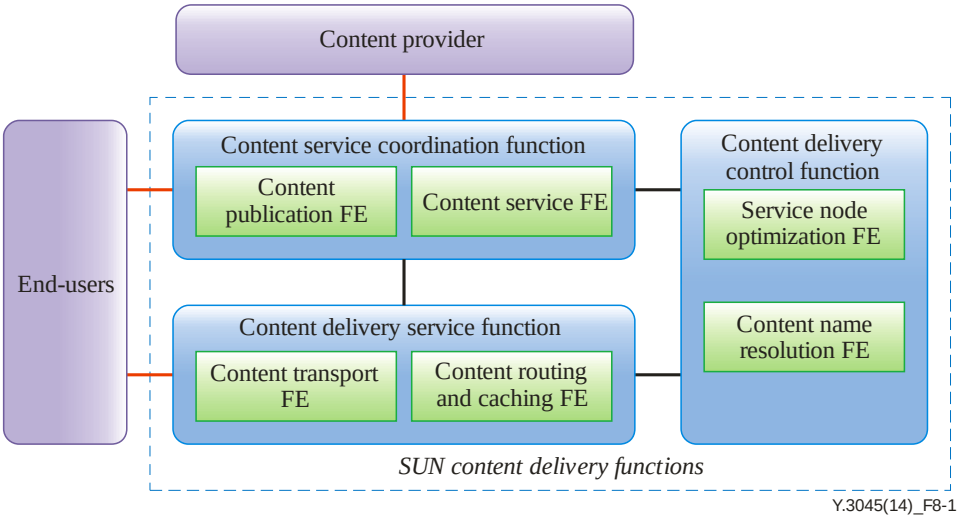

Figure 8-1 – Functional architecture of SUN content delivery

The SUN content delivery consists of three different functions which provide the aforementioned capabilities by interacting with themselves as follows:

– Content service coordination function (CSCF):
It coordinates content services between content providers and end users to handle the content publications by content providers and the content requests by end users.

– Content delivery control function (CDCF):
It controls content delivery to support content name resolutions and content routing.

– Content delivery service function (CDSF):
It provides the actual delivery of the content from content storages or content caches to end users.

While the details about CSCF and CDCF described in [ITU-T Y.3044] have different names of functional entities, their operations and interactions with the other relevant functions are fulfilled in this Recommendation by specifying corresponding functional entities and informational flows.

8.1 Content service coordination function

The content service coordination function (CSCF) takes a role of a gateway between the network and end users, and between the network and content providers. When a content provider requests content publication, CSCF registers and maintains the content information. CSCF further initiates to further download the content from the content sources and register it with publication information by CDSF and CDCF, respectively. When an end user requests content, CSCF redirects the request to the optimal service node that is determined by CDCF.

The functional entities of CSCF and their detailed operations are as follows.

– Content publication functional entity (CP-FE):
  - Handles publication requests from content providers
  - Generates a content ID for content published by content provider
  - Maintains content publication information.

– Content service FE (CS-FE):
  - Handles content requests from end users
  - Redirects content request to CT-FE instance in the selected service node.

    NOTE – It can be provided by different redirection mechanisms, such as HTTP redirection or DNS-based routing mechanisms.

8.2 Content delivery control function

The content delivery control function (CDCF) manages the information of network resources (i.e., service nodes), which hold the content in their local storages or caches to provide content location information according to the given content ID. Based on this information, CDCF also determines the optimal service nodes for content publications and content services.

The functional entities for CDCF and their detailed operations are as follows.

– Service node optimization functional entity (SO-FE):
  - Determines the optimal service node to which content is published
  - Determines the optimal service node by which a content request is handled
  - Evaluates service nodes based on proximity, network topology and availability
  - Maintains and monitors dynamic information (e.g., status, activity, performance, etc.) of service nodes.

– Content name resolution functional entity (CN-FE):
  - Manages (i.e., registers, deregisters and updates) the content ID with its content locators
  - Resolves a content ID by mapping it to multiple content locators.

8.3 Content delivery service function

The content delivery service function (CDSF) provides the content delivery from content providers to end users. Content delivery consists of several intermediate content delivery steps: (1) content download from content sources to content storages of service nodes, (2) content relaying and caching from content storages to content caches of intermediate service nodes along the content routing paths, and (3) content transport from content storages or caches to end users.

The functional entities for CDSF and their detailed operations are as follows.

– Content transport functional entity (CT-FE):
  - Downloads the published content from content provider (or content source)
  - Stores the downloaded content with its publication information
  - Transports the content from content storages or caches to the end user.

    NOTE 1 – The content can be delivered to end users via different transport mechanisms, such as streaming or file downloading.

– Content routing & caching functional entity (CR-FE):
  - Discovers content locations (i.e., storages or caches) by interacting with CN-FE
  - Fetches the content from the local content storage or cache
  - Relays and caches the content received along content routing paths.

    NOTE 2 – It can cache the whole content or place/replace the chunk-based caches of the content.

9 Content delivery operations

Figure 9-1 identifies the operations of SUN content delivery functions. The operations are categorized according to their target uses in the SUN content delivery capabilities.

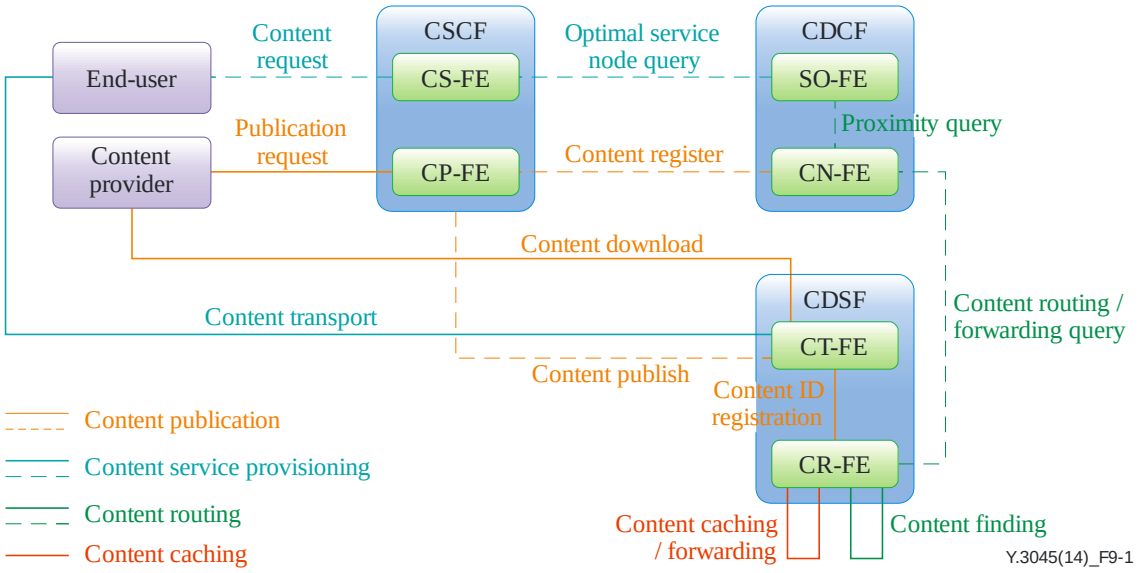

Figure 9-1 – Overall operations of SUN content delivery functions

9.1 Content publications

Content publication handles the requests of content providers for content registration to the service nodes with detailed content information including the location of content sources. Based on this content information, content delivery functions can discover the content which fits best to the user requirements and routes the content request to the content location (e.g., content source or local storages in the service node).

– Publication request:

  Content provider requests CP-FE to publish their contents.

– Content publish:

  CP-FE registers the content information and corresponding locations with CT-FE.

– Content downloading:

  CT-FE downloads the content from the content provider.

– Content register:

  CP-FE registers the downloaded content and its content ID with CN-FE.

9.2 Content service provisioning

Content service provisioning handles content requests from end users based on the given content ID. It discovers the optimal content location which can transfer the content to the end user efficiently in terms of location and traffic optimization according to the user context.

– Content request:

  End user sends a content request to CS-FE for routing and delivering the content from the service node.

– Optimal service node query:

  CS-FE queries SO-FE to select the optimal service node in terms of performance of content delivery to the end user.

– Content transport:

  CT-FE finally delivers the content segments or packets to the end user.

9.3 Content routing

Content routing discovers the content location based on the content locators determined by the content ID. The target content location (i.e., service node) fetches the content and transfers it to the requesting service node.

– Content finding:

  CR-FE discovers the content locations by routing the content request among the distributed CR-FE instances in service nodes.

– Content routing/forwarding query:

  CR-FE queries SO-FE about the content location of the given content ID for locating appropriate content sources or caches.

9.4 Content caching

Content caching distributes the content downloaded from the content source to the content caches in service nodes to optimize the content traffic by reducing the distance between the content source and end users.

– Content caching and forwarding:

  CR-FE forwards or relays the content from a service node to another service node and caches the content.

10 Informational flows

This clause provides the informational flows that complement the operations described in the previous clause.

10.1 Content publication

Figure 10-1 shows the informational flow for content publication where content providers request SUN to publish their contents.

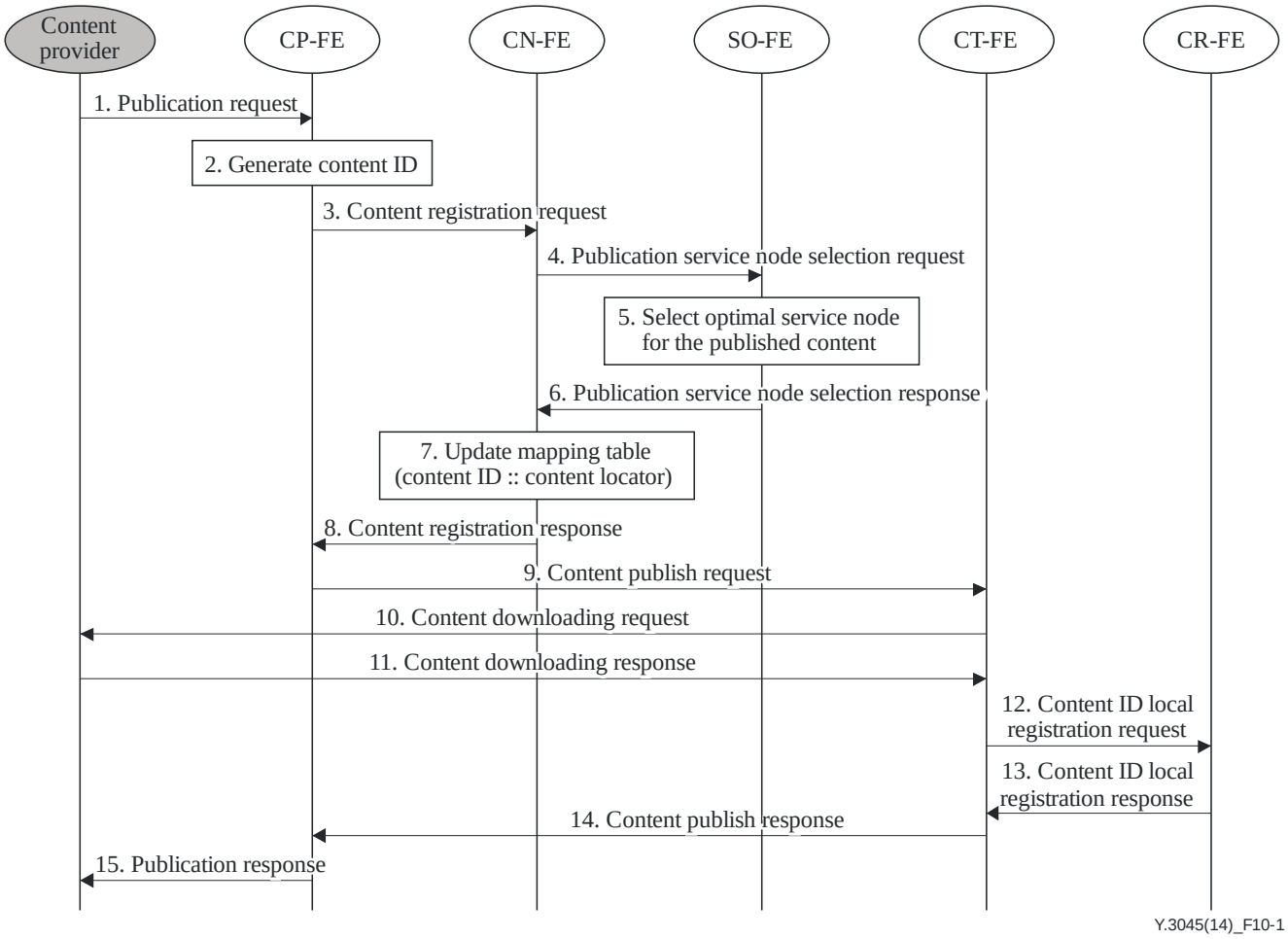

Figure 10-1 – Informational flow for content publication

1. The content provider requests CP-FE to publish its content. The content provider presents content information (e.g., URL and metadata) for content publication.
2. CP-FE generates an unique name (i.e., the content ID) for the content.
3. CP-FE requests CN-FE to register the content. CP-FE provides the generated name, URL and metadata for the content registration.
4. CN-FE queries SO-FE for the optimal service node where the content will be published.
5. SO-FE selects the optimal service node for publishing the content.
6. SO-FE notifies the locator of the determined optimal service node.
7. With the generated content name and notified locator, CN-FE updates a mapping table listing the locators associated with content names.
8. CN-FE responds to CP-FE with the locator of the optimal publication service node.
9. CP-FE makes a request for publishing content at CT-FE. CP-FE provides the content name and URL to CT-FE.
10. With the given URL, CT-FE tries to download the publishing content from the content provider.
11. The content provider provides its published content to CT-FE.
12. Once the content download is completed, CT-FE registers the content at CR-FE so that CR-FE can know the content availability.

13. CR-FE registers the downloaded content and responds to CT-FE with the result of local registration.
14. CT-FE responds to CP-FE with the result of content publication.
15. CP-FE responds to the content provider with the result of the publication request.

10.2 Content service provisioning

Figure 10-2 shows the informational flow for content service provisioning after a user's content request was redirected to CS-FE. Note that "*-FE (R)" and "*-FE (L)" indicate "remote *-FE instance" and "local *-FE instance", respectively.

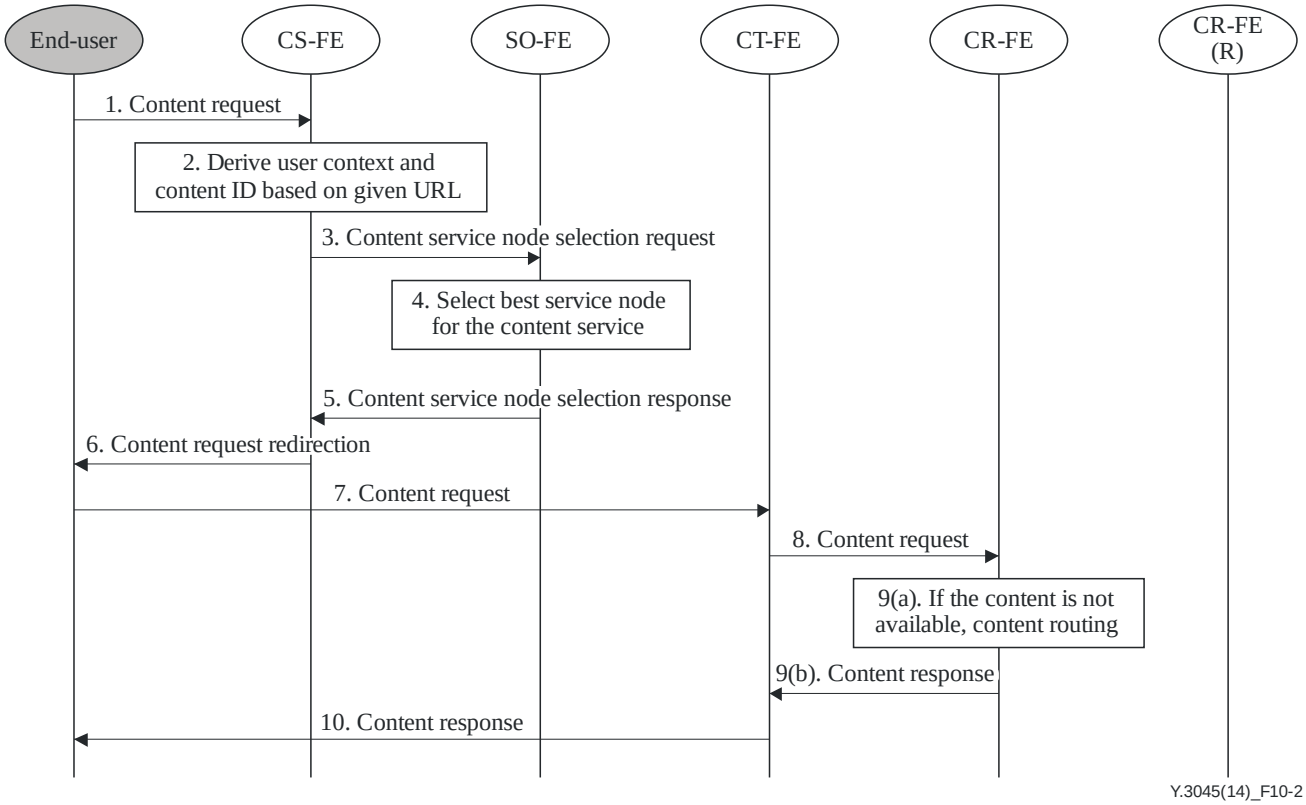

Figure 10-2 – Informational flow for content service provisioning

1. The end user requests content from CS-FE.
2. Upon receiving the content request from the user, CS-FE derives the user context information such as user IP address, content URL and user device information. Also CS-FE derives the unique name of the content <name of content> (i.e., the content ID) based on the content URL.
3. With the derived user context information, CS-FE queries SO-FE for the optimal service node that provides the content to users.
4. SO-FE selects the optimal service node for content service provisioning.
5. SO-FE notifies CS-FE of the locator of the selected optimal service node.
6. CS-FE requests the end user to redirect its content request toward the selected optimal service node.
7. The end user requests content from the CT-FE that is running in the selected optimal service node. To identify the content, the user makes use of <name of content> (e.g., the content ID).

8. CT-FE requests content from CR-FE with the <name of content> (e.g., the content ID).
9. (a) If the requested content is not registered to the CR-FE in the selected optimal service node, CR-FE initiates a name-based content routing. (b) Otherwise, CR-FE responds with the content.
10. CT-FE provides the content to the user.

10.3 Content routing

Figure 10-3 shows the informational flow for content routing to discover the content location.

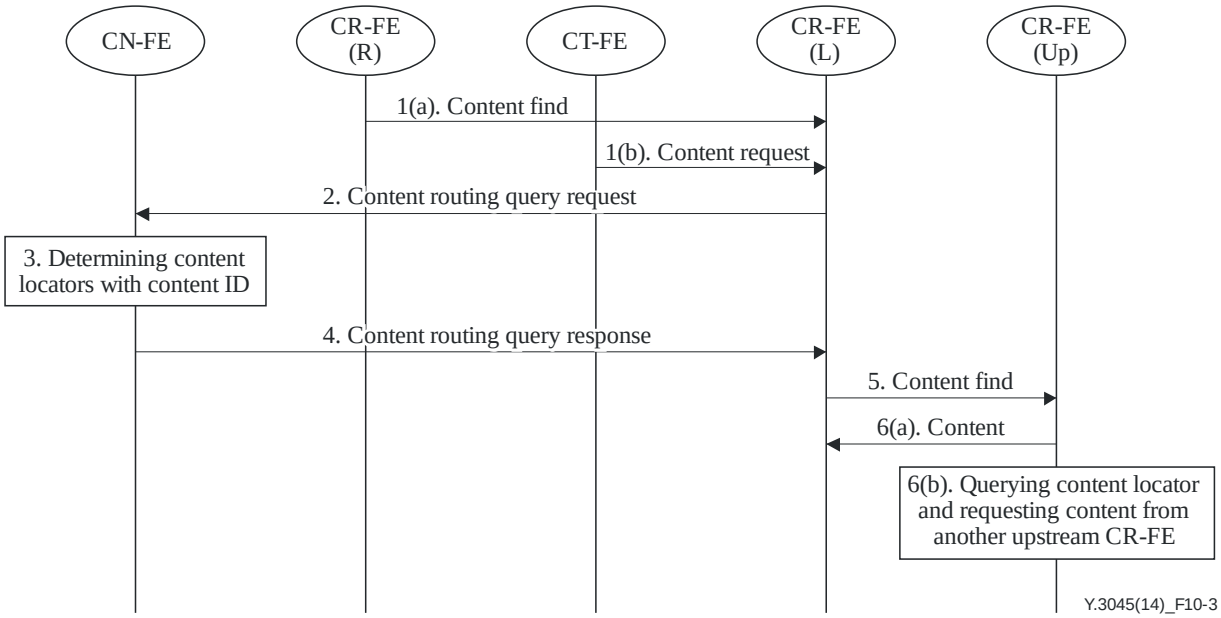

Figure 10-3 – Informational flow for content routing

1. (a) Content routing operations are initiated when the local CR-FE does not store or cache content requested by the local CT-FE. (b) The local CT-FE requests the local CR-FE to find content <name of content> (e.g., the content ID).
2. If the local CR-FE does not know the location of the content, it queries CN-FE for the content locators with the <name of content> (e.g., the content ID). The content locator is subject to be an IP address of the service node with additional forwarding information attached to it.
3. Upon receiving the content locator query, CN-FE resolves the content locator's binding to the <name of content>.
4. CN-FE responds to the local CR-FE with the content locator.
5. The local CR-FE sends a content request, using the content locator, to a remote CR-FE that is on the upstream path.
6. (a) If the remote CR-FE stores or caches the requested content, it transfers the requested content to the local CR-FE. (b) Otherwise, the remote CR-FE requests content from another remote CR-FE.

10.4 Content caching

Figure 10-4 shows the informational flow for content caching.

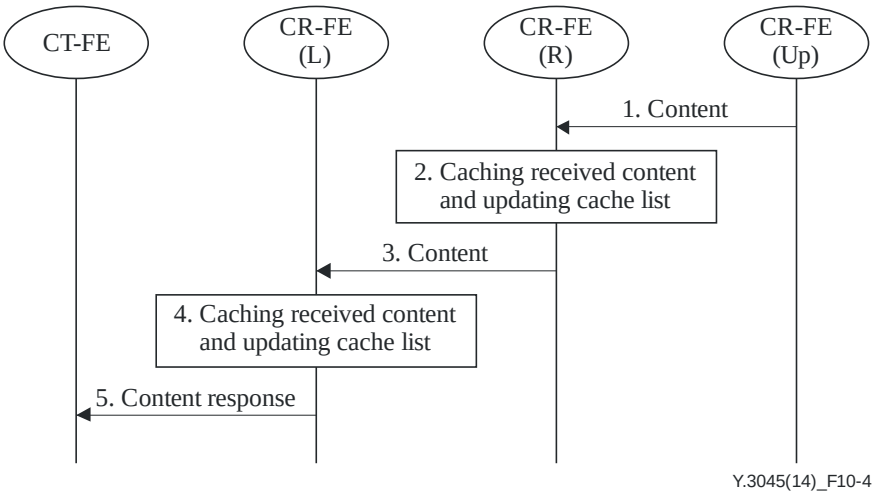

Figure 10-4 – Informational flow for content caching

1. The remote CR-FE receives the requested content from another remote CR-FE along the upstream path.
2. The remote CR-FE caches the received content in its storage and updates its caching list that maintains records of cached content.
3. The remote CR-FE forwards the received content to the local CR-FE that requested it.
4. The local CR-FE caches the received content in its storage and updates the caching list that maintains records of cached content.
5. The local CR-FE delivers the content response to the local CT-FE.

11 Environmental considerations

The SUN content delivery functions focus on the efficient content delivery by optimizing the traffic with content name-based routing and in-network caches. This capability can reduce the duplicated delivery of the same content and shorten the content delivery paths. Consequently, the reduced number of network elements for content delivery results in reducing the energy consumption of the network.

12 Security considerations

The SUN content delivery functions provide in-network storages and caches so that end users can directly retrieve the content from the intermediate service nodes in the network. In this case, the content provider cannot perform authentication, authorization and accounting (AAA) for the content delivery. Therefore, the SUN content delivery functions are required to provide additional security methods to perform AAA of end users on behalf of content providers.

13 Accessibility considerations

The SUN content delivery functions provide name-based content routing so that people with disabilities can utilize the content delivery more easily with human-readable content names rather than content location information such as IP addresses. The SUN content delivery functions also provide context-aware content delivery. Therefore, the content delivery functions can automatically adapt to the context changes, thus minimizing interruptions to people with disabilities.

Appendix I

Use cases for context-aware content delivery

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

Context-aware content delivery can be the bridge between knowing the mobile user's current situation and delivering related content for 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 delivery should be done in order to put the content into context.

This appendix describes a use case for context-aware content delivery that provides optimal selection of source and path based on the context information.

End users request the content provider to deliver the content that is located at multiple and distributed content sources in the network. Then the content provider redirects the user request to the SUN nodes, which are capable of context-aware content routing function (i.e., context-aware router). The context-aware router manages the context information by collecting, analysing and retrieving information periodically or dynamically from context sources. The context-aware router can decide which content source is the optimal one based on a combination of context information. An example of context information for the use case is as follows.

Table I.1 – An example of context information for the use case

Network context ranking		**Service context ranking**	
Ranking	Content source	Ranking	Content source
1	Content source #1	1	Content source #2
2	Content source #3	…	…
3	Content source #2	9	Content source #1 (overload)
…	…	10	Content source #3 (failure)

In terms of network context, content source #1 has the best proximity to the user because the IP address of content source #1 is "1.1.X.X". But, in terms of service context, the content-aware router excludes content source #1 because it is overloaded with too many sessions. Content source #3 has the second ranking in terms of network proximity; however, it is also excluded because the content-aware router finds a service failure on content source #3. Then, content-aware router decides that content source #2 has the optimal source and path to deliver the content to the user. Finally, the content-aware router redirects the user's request to content source #2, which will deliver the content.

Figure I.1 shows a procedural flow for the aforementioned use cases for context-aware content delivery.

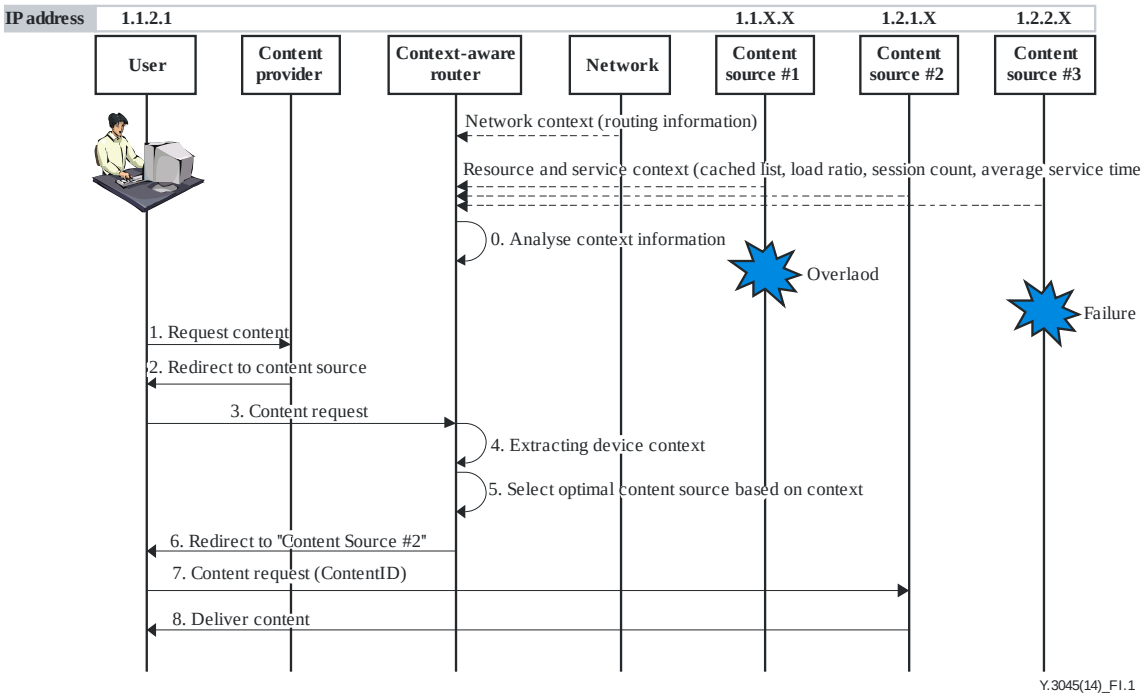

Figure I.1 – Use cases of context aware content delivery

<Pre-condition>

1. Context-aware router collects the network context from the network by capturing dynamically changing routing information.
2. Context-aware router collects the service context from the content source by collecting periodically or dynamically changing service status such as a list of caches, load ratio, number of sessions, average service time, etc.
3. Context-aware router periodically or dynamically analyses the aggregated context information and summarizes the context information in the abstract format such as ranking.
4. Content source #1 is experiencing overload because of too many service sessions.
5. Content source #3 accidently encounters service failure.

<Flow Description>

1. The end user sends a content request to the content provider.
2. Content provider redirects the content request to the content source using HTTP redirection or DNS-based routing mechanisms, for example.
3. Content request is redirected to the context-aware router.
4. Context-aware router extracts the device context, if it exists, from the content request.
5. Context-aware router selects the optimal content source based on the contexts and policies for determining content delivery paths. For example, if the network context has a high priority, content source #1 could be selected as the optimal source. But, in this example, content source #2 is selected because the context-aware router has a policy to consider both network and service context. In terms of service context, content source #3 is excluded because it does not have enough resources to deliver the content.

6-7. Content request is redirected to content source #2.

8. Content source #2 delivers the content requested.

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