International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.2815

(12/2018)

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Next Generation Networks – Generalized mobility

Mobility-supporting architecture for mobile peer-to-peer services in heterogeneous wireless networks

Recommendation ITU-T Y.2815

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Recommendation ITU-T Y.2815

Mobility-supporting architecture for mobile peer-to-peer services in heterogeneous wireless networks

Summary

Recommendation ITU-T Y.2815 specifies the mobility supporting architecture required for mobile P2P services in heterogeneous networks including cellular networks, WiMAX and WLAN. It covers the aspects related to functional requirements, architecture, high-level information flows and security considerations for mobile P2P users.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.2815	2018-12-14	13	11.1002/1000/13806

Keywords

Heterogeneous networks, mobile P2P, multiple interfaces.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Mobility-supporting architecture for mobile peer-to-peer services in heterogeneous wireless networks

1 Scope

This Recommendation describes the mobility-supporting architecture for P2P services in heterogeneous wireless networks. It provides the following: overview, functional requirements, functional architecture, high-level information flows and security considerations for mobile P2P users.

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.2018] Recommendation ITU-T Y.2018 (2009), *Mobility management and control framework and architecture within the NGN transport stratum*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 functional architecture [b-ITU-T Y.4406]: A set of functional entities used to describe the structure of an NGN. These functional entities are separated by reference points, and thus, they define the distribution of functions. The functional entities can be used to describe a set of reference configurations. These reference configurations identify which reference points are visible at the boundaries of equipment implementations and between administrative domains.

3.1.2 mobility [b-ITU-T Q.1706]: The ability for the user or other mobile entities to communicate and access services irrespective of changes of the location or technical environment.

3.1.3 mobility management [b-ITU-T Q.1706]: The set of functions used to provide mobility. These functions include authentication, authorization, location updating, paging, download of user information and more.

3.1.4 service continuity [b-ITU-T Q.1743]: The uninterrupted user experience of a service that is using an active communication (e.g., an ongoing voice call) when a UE undergoes a radio access technology change or a CS/PS domain change without, as far as possible, the user noticing the change.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 reputation: The history of a peer in terms of its link quality and contents.

3.2.2 resources: Information, process or bandwidth that is available to be accessed from other devices and networks.

3.2.3 terminal capability: The capability of a terminal for connecting to different networks by using related interface technology.

3.2.4 user preference: The user's favoured choice when selecting a suitable interface to a network based on different metrics such as energy, cost or bandwidth.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ATMF Access network Traffic Monitoring Function

CDF Content Downloading Function

CDP Content Downloading Peer

CRF Content Related Function

CUF Content Uploading Function

CUP Content Uploading Peer

EIF External Interface Function

ISN Intermediate Super Node

MIPF Meta-Information Processing Function

MPSF Mobile P2P Service Control Function

NGN Next Generation Network

P2P Peer to Peer

PoA Point of Access

PRF Peer Related Function

QoS Quality of Service

SPF Super peer function

UE User Equipment

UEMF User Equipment Status Monitoring Function

UMTS Universal Mobile Telecommunications System

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 document 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.

6 Overview

Traditional networks are based on the client-server model where the architecture is based on a server and a group of clients. Resources are managed and provided by the server and clients only ask for resources. By increasing the number of clients a new load is added to the server. To serve more clients and avoid a bottleneck in the system, server capacity should be increased. On the other hand, any fault and failure in the server as a bottleneck of the system or any security attacks can disrupt service provisioning.

P2P networks and related technologies provide scalability and fault-tolerance for applications in which a large number of users exist in an open distributed environment such as the Internet. In P2P networks, peers share their own resources including hardware and/or software resources, e.g., processing power, storage capacity, multimedia content, information services and content offered by the network to other peers directly without any intermediate central control entity. Today, P2P networks have gained attention widely in popular applications such as eMule or BitTorrent, and voice-over-P2P (VoP2P) applications such as Skype.

Developments in wireless technologies are performed in parallel with P2P networks in the telecommunication field. In mobile P2P networks, each mobile terminal is defined as a peer. Device terminals are independently connected to different networks with different technologies, P2P services such as file sharing and multimedia services can be managed in a distributed manner.

In next generation networks, multiple access networks with different simultaneous technologies, e.g., wide area networks (e.g., UMTS, HSDPA, HSPA+), metropolitian area networks (e.g., Mobile WiMAX (802.16e)], Mobile-Fi (802.20)), local area networks (e.g., 802.11a/g/n/p/s), personal area networks (e.g., Bluetooth, ZigBee, WiMedia) exist simultaneously. Each access network provides different levels of coverage, quality of service (QoS) and cost to the end users.

This brings forth a development that a P2P network can be hosted for a significant portion of mobile users. Users with multimode terminals can continuously roam between these access points and provide the minimum service quality and user preferences for their applications while using P2P services. Mobility management in the mobile P2P network is an important issue. Defining an appropriate management mechanism has an effect on the service performance achieved by the users in heterogeneous environments.

In this Recommendation, a mobility-supporting architecture is proposed for mobile P2P in heterogeneous wireless networks.

7 Functional requirements

7.1 General requirements

The general requirements are as follows:

– It is required to support mechanisms for mobility management of users, e.g., signalling and control architecture in heterogeneous networks in accordance with [ITU-T Y.2018].

– It is required to support mechanisms for discovering and selecting a UE's service profile from the P2P's agent in the user's terminal device.

– It is required to support capturing control context information for peer users when they change their access networks in case that mobility is supported.

– It is required to support the multi-homing ability for data transfer and receiving in mobile P2P networks.

– It is required to support user preferences for service support in P2P networks.

– It is required for assistance mechanisms to find the optimum method to discover resources and appropriate devices and interfaces for peer users.

– It is required for there to be resource agents, which are responsible for publishing resources, configuring resources, activating services and returning management interfaces.

– It is required to use particular mechanisms so that a peer can receive service from multiple peers simultaneously.

7.2 Service requirements

The service requirements are as follows:

– It is required to allow the delivery of services over different access networks with service continuity.
– It is required to use coding schemes in transmission according to the terminal capability, which are robust to QoS parameters for multimedia data.
– It is required to use mechanisms that provide reliability during services produced for UEs.
– It is required to use mechanisms that provide continuous service by using disconnection prediction of peers.
– It is required to deploy managers, which are responsible for obtaining P2P service specifications, mapping specifications to resources, discovering resources and gathering resources.

7.3 Network requirements

The network requirements are as follows:

– It is required that the network supports the monitoring of network status and information which can be used in access selection and content delivery.
– It is recommended that the network supports a resource management mechanism for unbalanced traffic volumes.
– It is required that the network supports connectivity with different kinds of network access technologies.

8 Service functional architecture

The functional architecture of mobile P2P services over heterogeneous access wireless networks is shown in Figure 1. The user equipment (UE) can become either a content downloading peer (CDP) or content uploading peer (CUP), depending on whether it is downloading or uploading the content. The mobile P2P functions are defined as a set of control functions for mobile P2P services.

– MPSF: Mobile P2P service control function;
– MIPF: Meta-information processing function;
– UEMF: User equipment status monitoring function;
– ATMF: Access network traffic monitoring function;
– SPF: Super peer function;
– CSF: Content storage function;
– EIF: External interface function;
– CDF: Content downloading function;
– CUF: Content uploading function.

These functions are described in detail in the following subclauses.

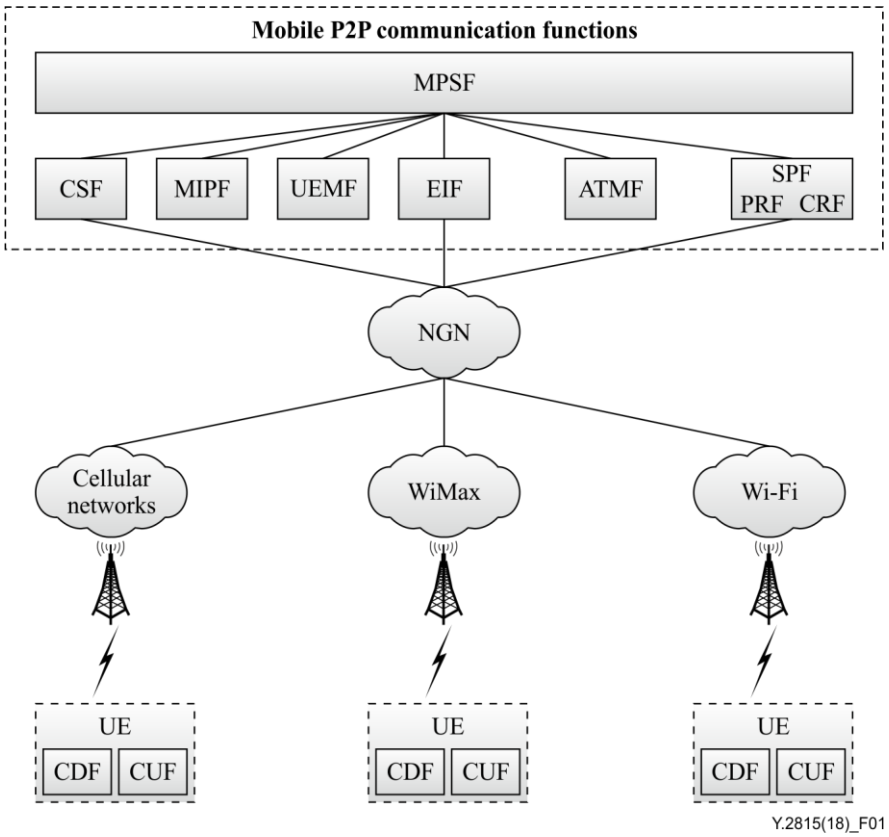

Figure 1 – Functional architecture of mobile P2P

8.1 MPSF

The MPSF consists of six subfunctions, which are as follows:

1) searching for user content and the UEs that can provide the content with the help of MIPF;
2) determining the status of the UEs (i.e., access networks, remaining battery power at UE, etc.) with the help of UEMF;
3) determining the traffic conditions in the access networks with the help of the ATMF. The MPSF may reconfigure P2P sessions in case of traffic congestion in the access networks and/or the radio outage of the CUP;
4) providing an interface necessary for communicating with a user device and a network management system (NMS) of each access network with the help of the EIF;
5) downloading the content that is located within the coverage of wireless networks that have a low transmission rate or a high wireless transmission fee and storing it. It can be done with the help of the CSF. The content can be transmitted to the UE whenever it connects to a proper network;
6) caching popular user content from selected CUPs with the help of the SPF.

In UE selection, the CUPs are selected among the UEs that have the requested content in a manner that the P2P traffic is distributed over wireless networks using idle radio resources so that ongoing P2P sessions are managed by monitoring the traffic in the access network. The use case related traffic distribution is provided in Appendix I (see Scenario-A). During the P2P content delivery stage, one or more CUPs may move out of the coverage of the access network that was chosen at the time of P2P connection setup. If the CDF detects the outage of a CUP, it informs the MPSF about the outage. Once the MPSF is notified, it reselects a new set of CUPs and an ongoing P2P session is reconfigured. In addition, by this function popular content is cached in the servers so that CUPs can avoid uploading the same content repeatedly.

8.2 MIPF

The MPIF manages information about user content (i.e., pictures, files, audios, videos, etc.). A user who wants to search content may send a keyword or metadata-based content search request to the MPSF using his or her UE, and the MPSF forwards this request to the MIPF. The MIPF searches for relevant content and sends the titles of the content and the IDs of the users who have the content's MPSF. The MPSF sends the titles of the content to UE and the UE displays the titles for the user who originated the search. If the user has decided to download the content, the user may enter a command and the UE sends a P2P session establish request to the MPSF.

8.3 UEMF

Upon receiving the P2P session establish request from the UE, the MPSF sends a query to the UEMF to determine the status of UEs that have the content. The UEMF collects information such as available access networks, transmission rates and transmission costs from UEs. The UEMF provides this information to the MPSF and the MPSF uses this information to choose a set of UEs that can upload the content.

For example, if two UEs that have the same user content have access to two different wireless networks; e.g., one with an expensive narrowband wireless access such as GSM and the other with an inexpensive broadband wireless access such as Wi-Fi, it would be cost effective and transmission effective to choose the latter as a CUP. If UEs have multiple wireless interfaces; e.g., both GSM and Wi-Fi, it would be cost effective and transmission effective to choose the UEs that are located within the radio coverage of the Wi-Fi network. Two use cases related to CUP selection considering cost are provided in Appendix I (see Scenario-A).

The information that the UEMF collects from the UEs may include, but not limited to:

– available access networks;
– available base station's and/or access point's identifiers;
– transmission cost of the available wireless access networks;
– transmission rate of the available wireless access networks;
– UE's remaining battery power;
– reputation factor in ranking based on past behaviours of the user in availability, connection reliability and trust.

8.4 ATMF

After the MPSF receives the status information of user devices from the UEMF, it sends a query to the ATMF to determine the traffic conditions in the access network. The ATMF may interwork with the NMS in each wireless network. As the ATMF reports the traffic conditions to the MPSF, the MPSF chooses UEs in the cells that are not crowded as CUPs. For one that can be chosen as a CUP, its point of access (PoA); i.e., its base station and/or access point, should have enough radio resource available not only for mobile P2P services but also for non-P2P services.

During the P2P content delivery stage, the ATMF keeps monitoring the traffic conditions in the base stations and/or access points that have CUPs within their coverage. If the amount of radio resource available at a PoA becomes smaller than a predetermined threshold, the ATMF notifies the MPSF and the MPSF reselects a new set of CUPs for the corresponding mobile P2P communication session.

8.5 EIF

The EIF provides interfaces for communicating with user devices and the NMS of access networks. In this case, the status of access network and UE's information are provisioned through the EIF, and CUF and CDF can communicate with P2P control functions through EIF. E.g., the CDF informs

MPSF about the outage of CUPs, and CUF can communicate with the UEMF and the MIPF through the MPSF with the help of EIF, as shown in Figure 1. It is also feasible that direct communication between CDF/CUF and the control functions may be performed without going through the MPSF, with the help of EIF.

8.6 SPF

The SPF includes two sets of functions: content related function (CRF) and peer related function (PRF), which are presented in clauses 8.6.1 and 8.6.2.

8.6.1 CRF

The CRF is used to avoid wasting battery power and radio resources of the UE, in cases where the UEs have popular content and have to upload the same content repeatedly. In these cases, the MPSF monitors the popularity of user content. When the MPSF detects popular user content it commands the SPF using the CRF to download the content from other UEs. The CRF in the SPF downloads the content as if it were another peer UE.

8.6.2 PRF

The PRF is used to determine and select the intermediate super nodes (ISNs) as potential peers used in extending P2P network coverage to help transmit requested content and increase the consistency of networks in a heterogeneous environment. The duties of the PRF are to find the best new ISNs for handling peers' traffic in indirect cases and distributing the peers' load across the network topology. ISNs could be used as intermediate peers to forward messages to PoAs, if a direct link is beyond their communication range.

The PRF should use some selecting protocols to find new ISNs while periodically building a set of ISN candidates, tracking ISNs and maintaining their connections with a low overhead of control messages. ISN selection is based on many factors that influence the selection decision, which have a direct impact on the peer's performance. Because mobile environments pose additional challenges to ISN selection, due to the constantly changing topology and the various constraints stemming from the limited capability, heterogeneity of nodes, limited resources and dynamic contexts of wireless networks. Therefore, the selection algorithms for defining the subset of ISNs should use a peers' properties to evaluate their candidacy and rank peers for the ISN role. The selection metrics can be categorized in relation to the ISNs' capabilities and contexts as follows:

- Content-related metrics
  - candidate ISN's content
- UE-related metrics
  - battery level of candidate ISN's UE
  - mean uptime and connectivity degree of candidate ISN's UE
  - velocity of candidate ISN's UE
  - computational resource of candidate ISN's UE.
- Connection-related metrics
  - bandwidth of candidate ISN
  - average transmission rate of candidate ISN
- UE preferences

8.7 CSF

When a user who wants the content is located under the coverage of narrowband wireless networks (e.g., 2G or 3G) where the transmission rate is low and/or transmission cost is high, the user may request the MPSF that the content to be uploaded from the peer users to the CSF located in the

wired network instead of downloading the content directly to the user's mobile equipment. When the user moves into the coverage of a broadband wireless network with a high transmission rate or a low transmission cost, the user may download the content stored in the CSF to the user's mobile equipment using the broadband wireless networks, e.g., Wi-Fi network.

9 High-level information flows

9.1 Registration of mobile P2P

The following procedural flow represents the high-level sequence of flow for a mobile peer registration. This procedure is initiated when a user starts a P2P service in the UE.

1) A mobile peer node starts a P2P service.
2) A 'registration request' is sent by the mobile peer node to the MPSF. The registration request contains available content in mobile peer, its link address and network status.
3) The MPSF sends the MIPF the received information, including the available content in the mobile peer. The MIPF uses this information for selecting the CUPs to deliver the content to the MPSF in the cases where a mobile peer queries content from the MPSF.
4) The MPSF sends the UEMF the received information, including the address link and network status. The UEMF uses this information for selecting the CUPs according to peers' links and network statuses.
5) A "Registration Response" is sent to the UE by the MPSF.

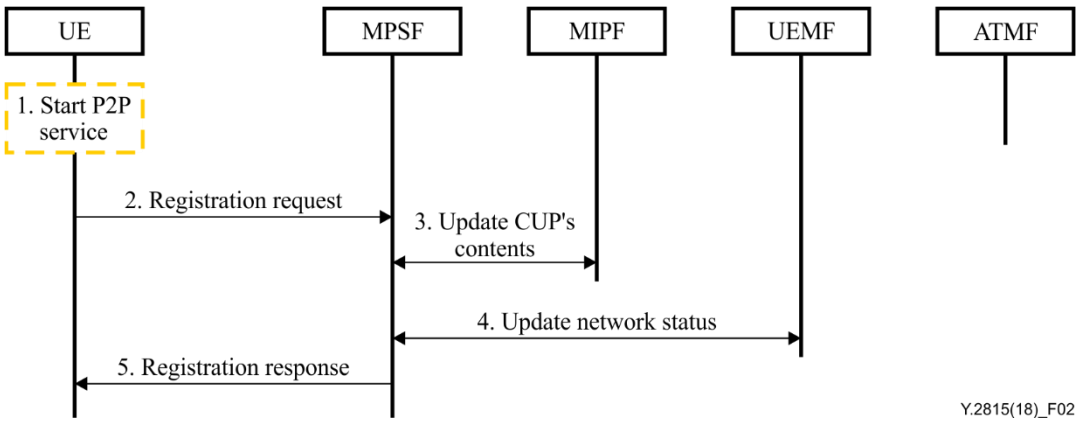

Figure 2 – Registration of mobile P2P

9.2 Updating mobile peer-related information

The following procedural flows represent the high-level sequence of flows for updating mobile peer-related information. The update procedure is required in two cases:

– mobile peer handover;
– changing the content of the mobile peer in CUP mode.

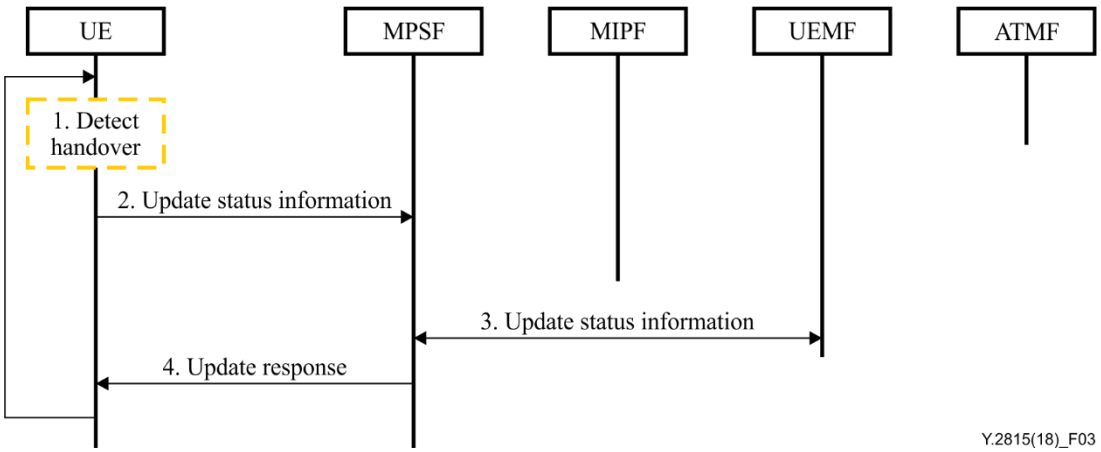

Figure 3 – Handover management of P2P peer

The procedural flow of mobile peer handover is listed as follows:

1) The handover is detected by the UE.

2) When the UE detects handover, the mobile peer sends a query to the MPSF for updating status information.

3) The MPSF updates reported changes, including the network status of the mobile peer used in the UEMF. This information can be used in two cases: (a) If the mobile peer acts as the CDP, in the case that the new access network has a high transmission cost, the procedure will be led to save the requested content in the CSF. (b) If the mobile peer acts as the CUP, since the environment is heterogeneous, the procedure will be led to reselect a new CUP based on the status of the mobile peer, e.g., transmission rate, transmission cost, battery level.

4) After the update procedure, the update response is sent to the mobile peer by the MPSF.

This procedure is a periodic operation of reporting mobile peer-related information including any change in the access status or the content. The period of update procedure can be configured dynamically.

The procedural flow of content changing of the mobile peer in CUP mode is presented as follows:

1) The content changing is detected by the UE.

2) When content changing occurs, an update content information is sent to the MPSF.

3) The MPSF sends the CUP's content information to the MIPF. The MIPF uses this information for delivering to the MPSF when it needs to select CUPs in the cases where a mobile peer queries content from the MPSF.

4) An update response is sent to the mobile peer by the MPSF.

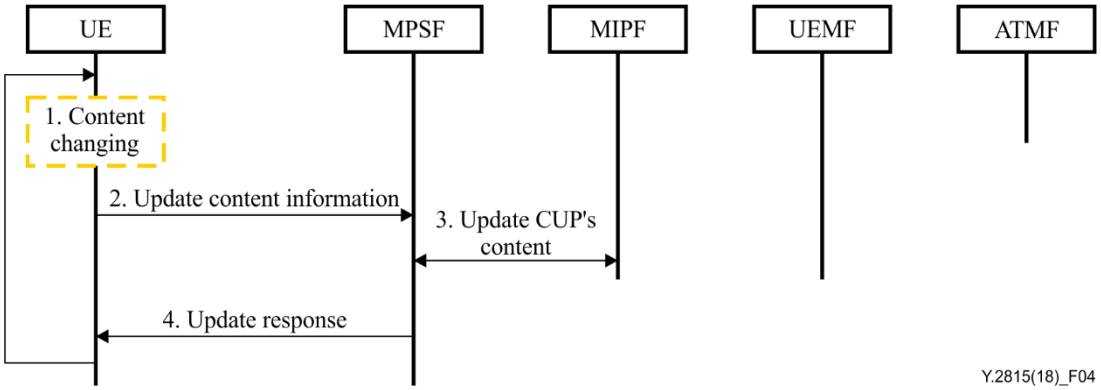

Figure 4 – Content changing of CUP

9.3 Mobile P2P selection by considering traffic status

The following procedural flows represent the high-level sequence of flows for traffic management of the mobile peer that requests P2P services in a heterogeneous environment.

Precondition: It is assumed that the mobile peer has been registered for using a P2P service.

1) A request is initiated by the user for specific content.
2) The CDF sends the request to the MPSF for searching content that the user wishes to receive.
3) The MIPF searches the requested content. A list of found content and candidates as the CUPs are delivered to the MPSF by the MIPF. It is the result of the MPSF query from the MIPF.
4) The content search response is sent to the CDF.
5) The preferred content from the received content list is requested by the user.
6) The CDF sends the MPSF a request to establish a P2P session for downloading preferred content.
7) The candidate CUPs' status (including requested content) is determined by using a query/response procedure between the MPSF and UEMF.
8) The PoA traffic conditions of candidate CUPs are determined and reported to the MPSF by the ATMF during the query/response procedure.
9) The MPSF selects UEs as the CUP in the cells that are not crowded while considering other parameters such as transmission rate, transmission cost and battery level.
10) The MPSF sends a response for establishing a P2P session between the CDP and the CUPs.
11) The CDF establishes a P2P session with the CUPs that are proposed by the MPSF and starts to download the preferred content.
12) To use available resources in the network efficiently, a request is sent to the ATMF by the MPSF for monitoring the traffic of PoA used by the CUPs.
13) The ATMF monitors the traffic load of the PoA.
14) The ATMF checks the traffic congestion in the PoA.
15) A notification is sent to the MPSF by the ATMF if a PoA is detected as a congested PoA.
16) Reselect CUPs: Steps 7 to 9 are repeated to select other CUPs if it is needed for the downloading content.
17) A P2P session re-establishing request is sent to the CDF for new selected CUPs.
18) A new session is established to continue downloading content from a new set of CUPs.
19) The MPSF sends the ATMF traffic monitoring request. Traffic monitoring is continued until the requested content is downloaded.

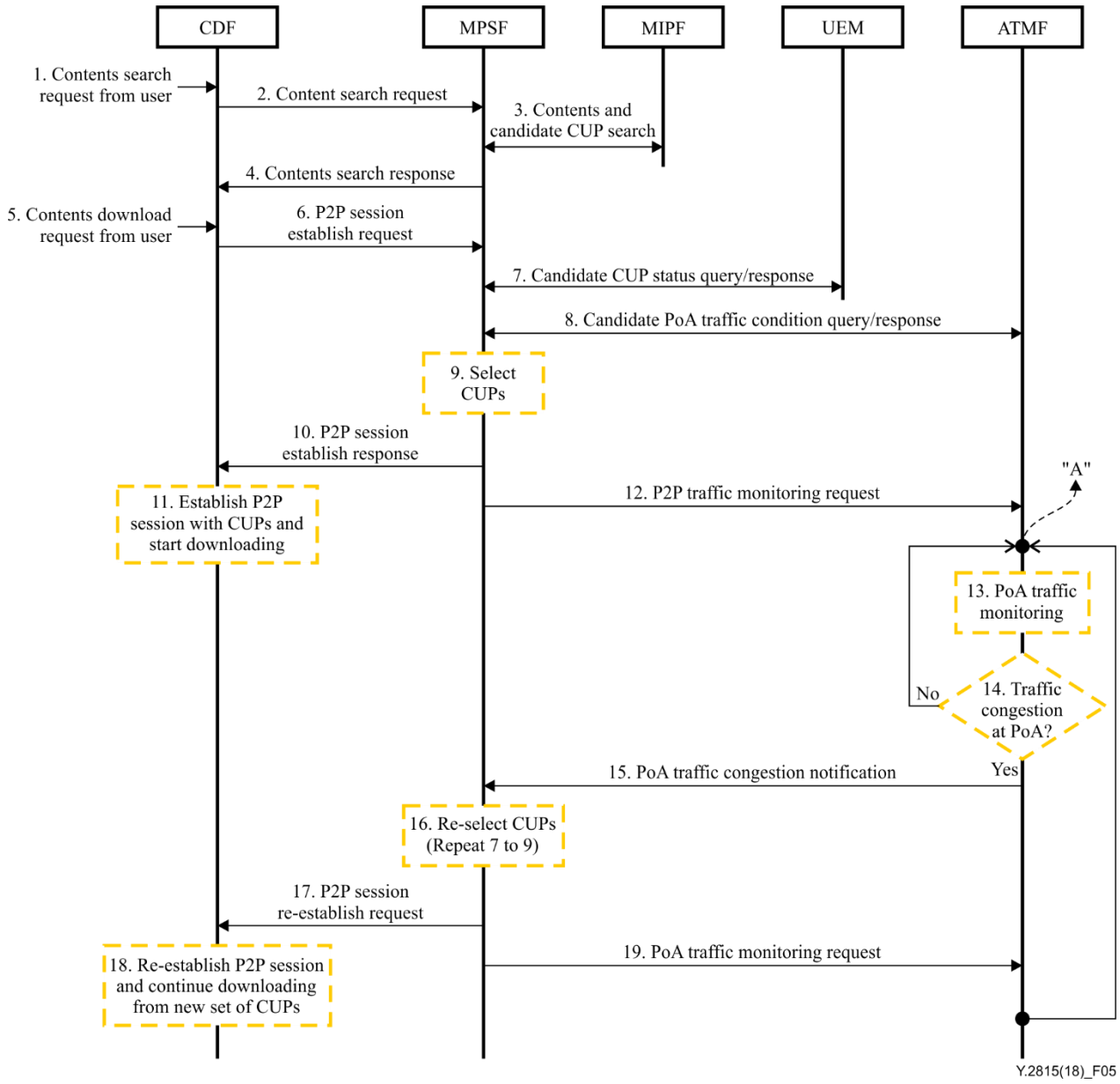

Figure 5 – Mobile P2P selection by considering traffic status

9.4 CUP outage management

The following procedural flow represents the high-level sequence of flows for outage management of the CUP while user content is downloaded from the CUPs to the CDP.

Precondition: It is assumed that the mobile peer is downloading the content from the CUPs and in this time, one or more CUPs that provide the required content of the CDP may move out of the radio coverage of the access network. The CUPs have been chosen at the time of initial P2P session setup.

1) When a CUP has lost radio connection to its access point, the data transmission from the CUP to the CDP is interrupted and the CUPs' outage is detected by the CDP.

2) The CDF informs the MPSF about the outage of one or more CUPs.

3) New candidate CUPs that contain downloading content are listed by query/response between the MPSF and the UEMF.

4) Interaction between the MPSF and the ATMF helps in determining the traffic conditions of the PoA which the CUPs are connected to.

5) New CUPs are selected based on CUPs' status and traffic conditions of their PoA.

6) The MPSF reselects a new set of CUPs and for the purpose of reconfiguring the P2P session, a new request is sent to the CDF.

7) The CDF re-establishes a new P2P session to continue downloading requested content.

8) The MPSF sends request for traffic monitoring of the PoA.

9) The traffic monitoring of the PoA is performed periodically. The period of traffic monitoring can be configured dynamically.

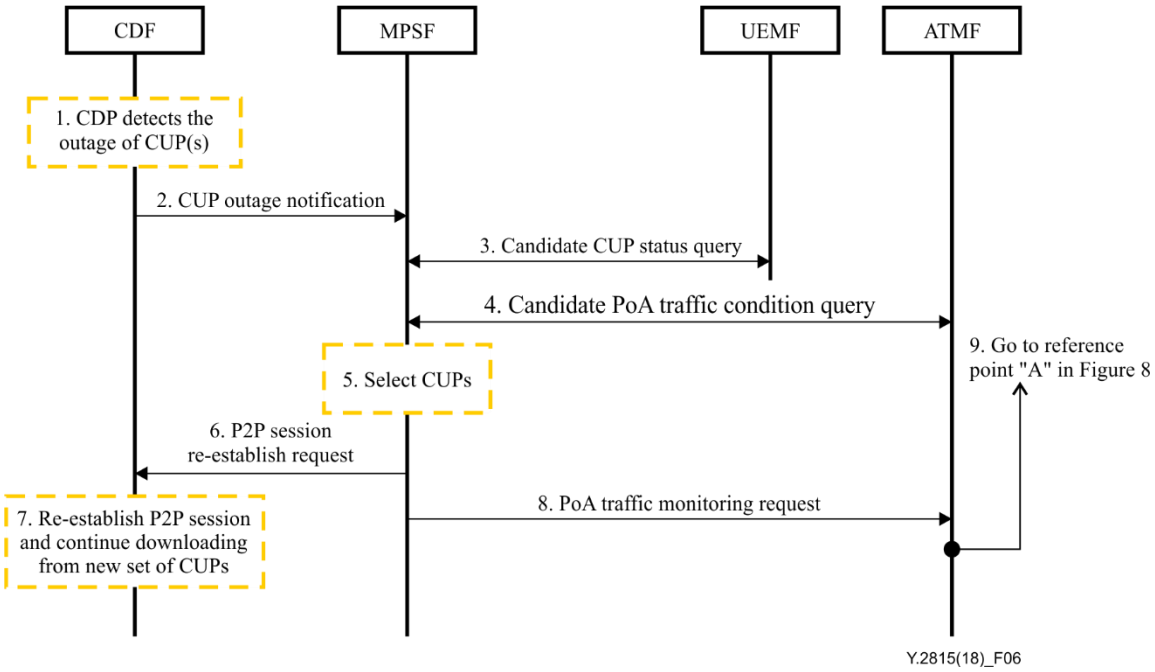

Figure 6 – Functional architecture of Mobile P2P

9.5 Mobile P2P service termination

The following procedural flow represents the high-level sequence of flows for mobile P2P service termination.

Precondition: It is assumed that the mobile peer is connected to the network and has been using a P2P service to download requested content.

1) The CDF is notified about the completion of content download.

2) A notification is sent to the MPSF by the CDF to inform about the completion of content download, for the purpose of releasing the current resources.

3) The MPSF requests the ATMF to release its resources that they were allocated to the PoA traffic.

4) At the end the ATMF terminates PoA traffic monitoring.

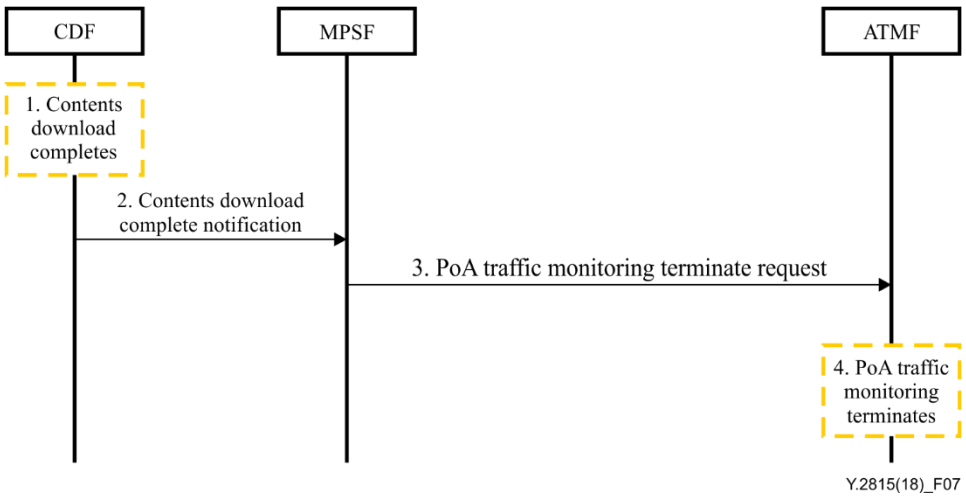

Figure 7 – Mobile P2P service termination

9.6 Indirect content delivery using CSF

The following procedural flows represent the high-level sequence of flows for indirect content delivery using the CSF.

Precondition: It is assumed that the mobile peer could not download the required content due to an inefficient condition in terms of the transmission rate or transmission cost. At this time, the user requests the CSF to download the required content.

1) A request is initiated from the user for specific content.
2) The CDF sends a content search request to the MPSF for content that the user wishes to receive.
3) The MIPF searches the relevant content and their related user IDs. A list of content and candidate CUPs are delivered to the MPSF by the MIPF, which is the result of the MPSF query from the MIPF.
4) The content search response is sent to the CDF.
5) The selected content in the received list is requested by the user.
6) Since the user is located in a low transmission rate or high transmission cost access network, e.g., 2G network, the CDF sends the MPSF a request for uploading required content from the CUPs to the CSF. The uploaded content may be downloaded by the user when his or her mobile equipment is located in the coverage of a high transmission rate and/or low transmission cost access network.
7) The candidate CUPs' status (including requested content) is determined by using the query/response procedure between the MPSF and the UEMF.
8) The PoA traffic condition of candidate CUPs is determined and reported to the MPSF by the ATMF during the query/response procedure.
9) The MPSF selects CUPs in the cells that are not crowded while considering other parameters such as transmission rate, transmission cost and battery level.
10) The MPSF sends the CSF a request to establish a P2P session with the CUPs for downloading the requested content.
11) The CSF establishes the P2P session with selected CUPs to download the requested content.
12) The MPSF sends the ATMF a request to monitor the PoA traffic. This helps the network to use its resources efficiently.
13) PoA traffic monitoring is started by the ATMF.

14) The ATMF checks traffic congestion periodically to track available resources in the PoA.

15) If a PoA is congested a notification is sent to the MPSF for new CUPs.

16) Steps 7 to 9 are repeated to select other CUPs for the downloading content.

17) The MPSF sends the CSF a P2P session re-establishing request for new sessions with selected CUPs.

18) A new session is established to continue downloading content from a new set of CUPs.

19) A request is sent to the ATMF by the MPSF for monitoring traffic of the PoA, which CUPs are connected to. Traffic monitoring is continued until the requested content is downloaded.

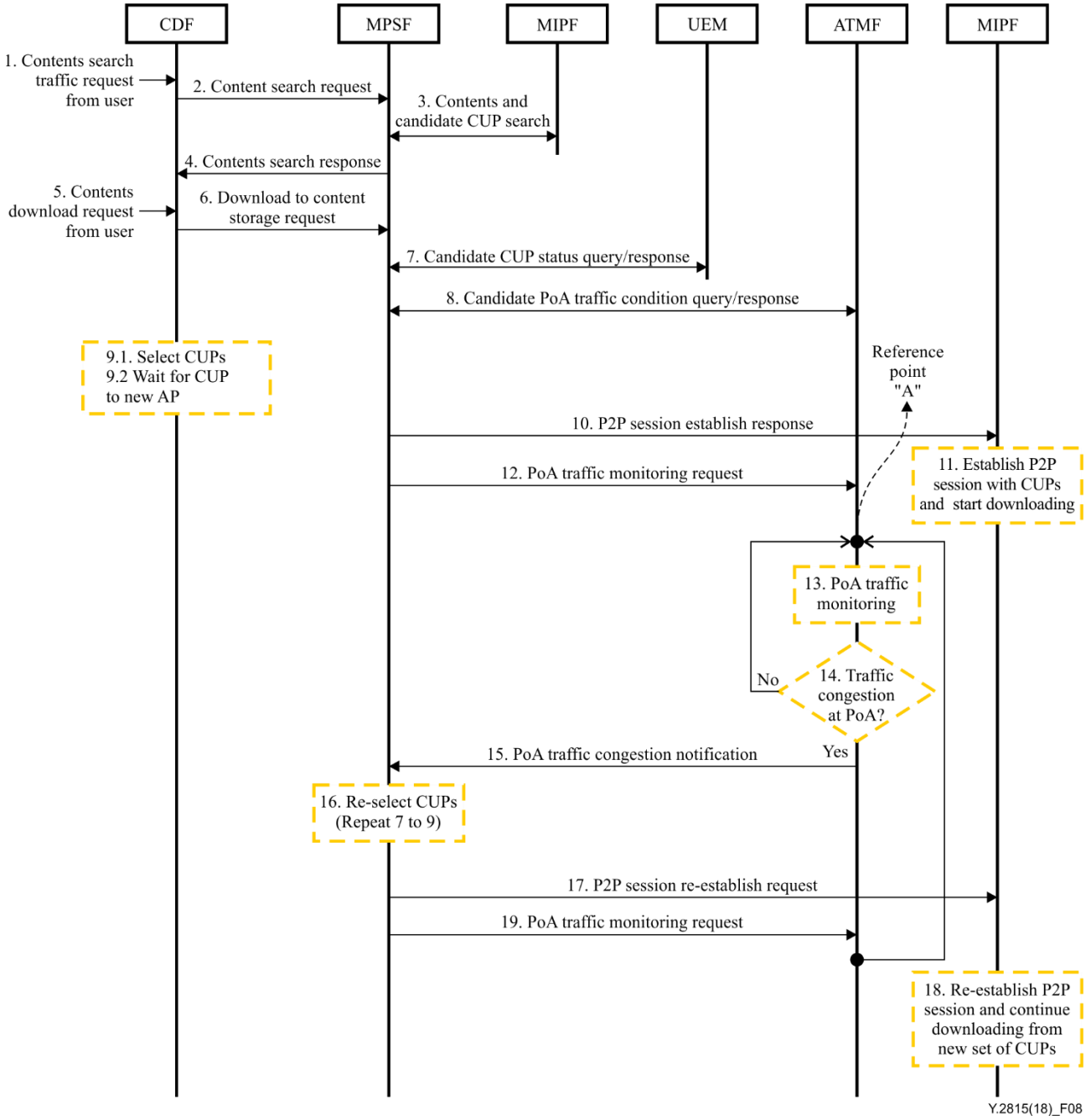

Figure 8 – Indirect content delivery using CSF

10 Security Considerations

Mobile P2P in heterogeneous networks should support the following security considerations:

– The applied security issues are recommended to support security mechanisms from different perspectives, including the service, network and user.

– Applied security considerations should not generally affect service quality.

– Security provisioning should be simple for both subscribers and network providers.

Appendix I

Mobile P2P scenarios

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

A P2P service has proliferated in wired networks since the transmission cost is relatively cheap, and users do not worry about the amount of traffic uploaded from their UEs. In wireless networks, however, users usually pay for radio access based on the amount of traffic transmitted and received through a radio link, and they may not want to upload their files to anonymous peer users just for the purpose of information sharing.

From the perspective of the wireless network service provider, the cost of radio transmission for P2P services can be made less if a P2P network is designed to utilize idle radio resources and avoid congestion in radio access networks. To avoid radio traffic congestion a P2P control plane should have capabilities to monitor the traffic condition in the radio access network and adaptively reconfigure P2P connections when the radio traffic congestion is detected or foreseen.

Scenario-A: Cost-effective peering

If two P2P users $P_{A,Wi\text{-}Fi}$ and $P_{B,cellular}$ have the same video clip stored in their UEs, where $P_{A,Wi\text{-}Fi}$ is connected to a Wi-Fi network and $P_{B,cellular}$ is connected to a UMTS (Universal Mobile Telecommunications System) network, then $P_{C,cellular}$ which is connected to the same base station as $P_{B,\ cellular}$ should download the video clip from $P_{A,Wi\text{-}Fi}$ since the radio transmission cost of Wi-Fi is much less than that of UMTS.

If the Wi-Fi network and UMTS network are operated by different operators and the cost of inter-operator traffic exchange is not negligible, and if the UMTS base station has an idle radio resource to accommodate the extra P2P traffic, $P_{C,UMTS}$ may download the video clip from $P_{B,\ UMTS}$.

Scenario-B: Traffic-sensitive peering

Assume that two P2P users $P_{A,Wi\text{-}Fi}$ and $P_{B,UMTS}$ have the same video clip stored in their UEs, and $P_{C,UMTS}$ which is connected to the same base station as $P_{B,UMTS}$ has established a P2P connection with $P_{B,UMTS;}$ if the base station has become crowded with new mobile users, then $P_{C,UMTS}$ should stop downloading a video clip from $P_{B,UMTS}$ and start establishing a new P2P connection with $P_{A,Wi\text{-}Fi}$ to download the rest of the video clip.

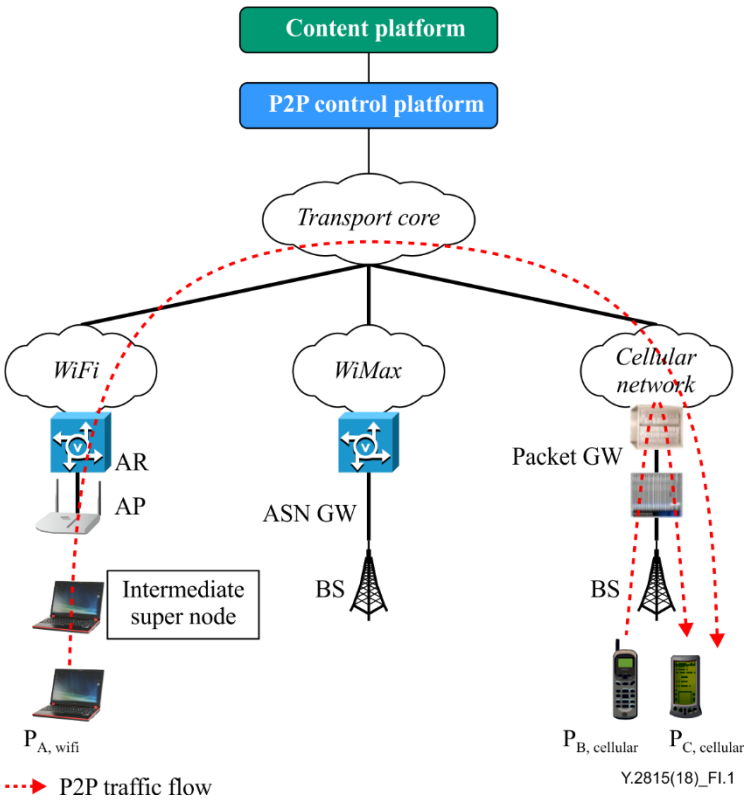

Figure I.1 – Cost-effective and traffic-sensitive dynamic peeing scenario

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Printed in Switzerland
Geneva, 2019