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

Next Generation Networks – Frameworks and functional architecture models

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A multi-path transmission control in multi-connection

Amendment 1: New Annex A – Network equipment-based multipath transmission

Recommendation ITU-T Y.2029 (2015) – Amendment 1

ITU-T Y-SERIES RECOMMENDATIONS

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

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	**Y.2000–Y.2099**
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	
General	Y.4000–Y.4049
Definitions and terminologies	Y.4050–Y.4099
Requirements and use cases	Y.4100–Y.4249
Infrastructure, connectivity and networks	Y.4250–Y.4399
Frameworks, architectures and protocols	Y.4400–Y.4549
Services, applications, computation and data processing	Y.4550–Y.4699
Management, control and performance	Y.4700–Y.4799
Identification and security	Y.4800–Y.4899
Evaluation and assessment	Y.4900–Y.4999

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Recommendation ITU-T Y.2029

A multi-path transmission control in multi-connection

Amendment 1

New Annex A – Network equipment-based multipath transmission

Summary

Amendment 1 to Recommendation ITU-T Y.2029 introduces Annex A, which provides the text of network equipment-based multi-path transmission, including the necessity and technical considerations, capability requirements, scenarios and information flows for supporting network equipment-based multi-path transmission.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Multi-path transmission, network equipment

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Recommendation ITU-T Y.2029

A multi-path transmission control in multi-connection

Amendment 1

New Annex A – Network equipment-based multipath transmission

1) Scope

Amendment 1 introduces Annex A (network equipment-based multi-path transmission), which covers the following:

− The necessity and technical considerations,

− Capability requirements and scenarios,

− Information flows for supporting network equipment-based multi-path transmission.

2) Additions

2.1) Abbreviations and acronyms

Add new abbreviations in clause 4 as follows:

NE Network Equipment

MPT Multi-Path Transmission

2.2) Annex A

Add a new Annex A as follows:

Annex A

Network equipment-based multi-path transmission

(This annex forms an integral part of this Recommendation.)

A.1 Overview

A.1.1 The necessity of network equipment- based multi-path transmission

With the widespread of mobile devices, the overall network traffic has significantly increased. To support increased traffic with various requirements (e.g., quality of service, etc.), the concepts of multi-connection and multi-path transmission (MPT) are introduced. Although MPT can be initiated by both user equipment (UE) side and network equipment (NE) side, the NE based MPT has several advantages compared to the UE based MTP which are as follows:

- Network management

In the case of UE based MPT, connection and transmission are initiated and managed by the UE; therefore, from the perspective of network operators, the NE has no control and passively handles each sub-transmission flow created by the UE. However, from the network management perspective, even if the UE has no MPT functionality, the NE needs MPT functionality (e.g., creating sub-transmission flows within the network) for increasing network resource utilization (e.g., traffic management, congestion control, load balancing, etc.).

- Application overhead of the UE side

To support UE based MPT, some applications of the UE side may be able to choose multiple access network interfaces before setting up actual sub-transmission flows for data exchange. To support MPT functionality at the application level, application developers need to make additional efforts to incorporate the possibility of multi-connection through multiple network interfaces. However, in the case of NE based MPT, all required procedures for MPT are performed by the NE, which means that the applications do not need to consider the multi-connection scheme.

- Energy consumption on the UE side

UE based MPT requires one or more network interfaces operated at the same time. For example, if a user device simultaneously operates Wi-Fi and long-term evolution (LTE) for MPT, the UE consumes more resources and energy to maintain multiple connections. However, the UE usually has resource and energy limitations. With NE based MPT, each UE can achieve higher performance without additional efforts because the NE can optimize paths for each sub-transmission flow depending on the condition of the network.

Table A.1 shows the comparison of MPT initiated and managed by the UE side and the NE side. NE based MPT has differences when compared to UE based MPT. As mentioned in Table A.1, there is no burden on the maintenance and management of the multi-path connection of the UE in terms of energy consumption. There are also no additional requirements for related networking resources. It is not necessary to implement software types of functions related to MPT in the applications of the UE side. Therefore, it is necessary to develop the concept of NE based MPT. Consequently, this annex focuses on NE based MPT by describing technical considerations, relevant functional entities, target scenarios and some information flows.

Table A.1 – Comparison between UE based MPT and NE based MPT

Affecting factors	UE based MPT	NE based MPT
Network management	NE has no control and passively handles each sub-transmission flow created by MUE	NE create sub-transmission flows for network resource utilization
Application in the UE side	UE is required to support MPT functionality	UE can optionally support MPT functionality
Energy consumption of the UE side	High	Low

A.1.2 Technical considerations for NE based MPT

- Multi-path transmission in the network

For MPT, three major cases should be covered: i) MPT in a single network domain, ii) MPT in multiple network domains, and iii) MPT through an inter-network domain. Since the NE in the network has the original path configuration for ordinary connections, MPT mechanisms should be able to cover various path configuration schemes and various network environments. Particularly, path selection schemes for MPT should be compatible with the existing schemes.

- Packet delivery

Each sub-transmission flow created by a sender NE for MPT from the single original flow should be reliably delivered to the final receiver NE by keeping the original flow and by satisfying packet delivery requirements (e.g., packet sequence, delay, etc.). With the proper packet forwarding schemes, in-order and reliable delivery mechanisms should be considered. In addition, mechanisms for handling exceptional cases such as differential delay issues, packet re-ordering, and network buffer management should also be considered.

- Load balancing and congestion control

With NE based MPT, traffic flow is split into multiple sub-transmission flows, and they are distributed into concurrent transmission paths. NE can utilize MPT for load balancing techniques to avoid network hotspots. Therefore, load balancing methods should be considered to efficiently manage each sub-transmission flow. Moreover, network congestion control should also be considered.

- Network resource utilization

When the NE decides to initiate MPT for increasing network resource utilization, the NE should consider both the number of sub-transmission flows and their achievable throughput based on the requirements. Particularly, MPT can be used to create another sub-transmission flow for achieving higher resource utilization by concurrently handling multiple sub-transmission flows.

A.2 NE-based multi-path transmission

A.2.1 Capability requirements

Figure A.2-1 shows major functional entities for NE based MPT, UE based MPT and multi-connection control based on the functional architecture in clause 6 of [ITU-T Y.2027]. The following are additional capability requirements for supporting NE based MPT:

– NE is required to be enhanced for the multi-path transmission support like path assessment, path status maintenance and implementation of traffic management related functionalities,

– Multi-connection policy control function entity (MPC-FE) is required to be enhanced to support a specific multi-path transmission policy decision algorithm for multi-path transmission between the sender NE and the receiver NE,

– Service control function (SCF) is required to be enhanced as a multi-path transmission proxy to transparently provide multi-path capability and support path assessment and adjustment decision mechanisms to support multi-path transmission between the sender NE and the receiver NE.

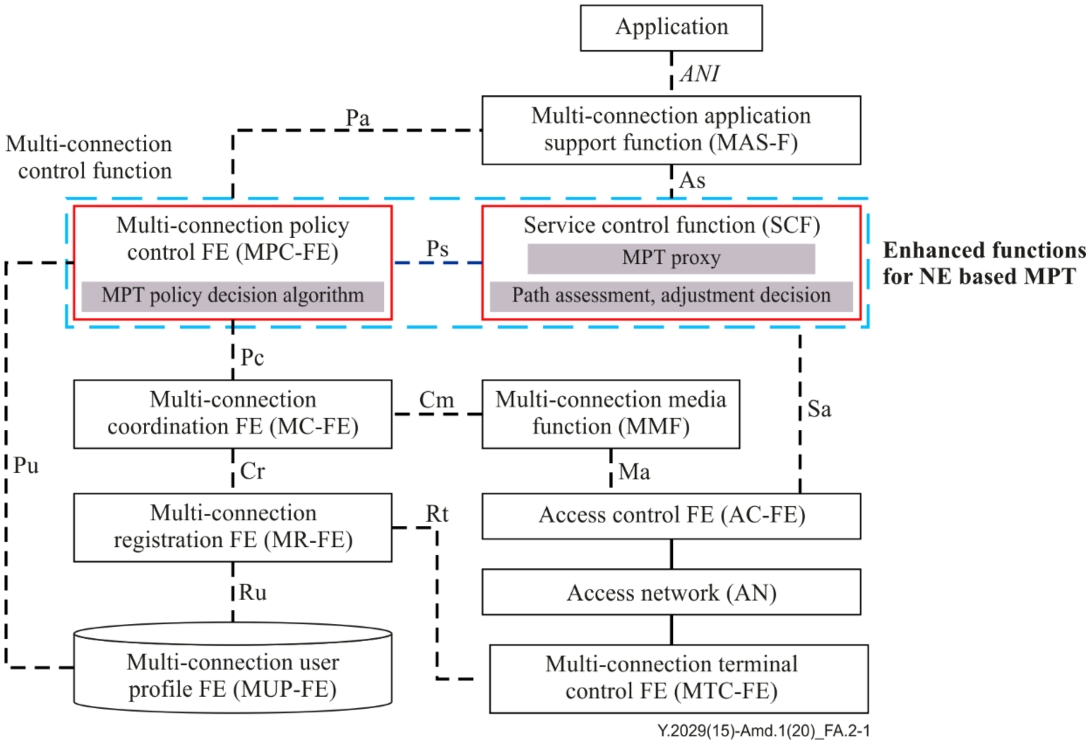

Figure A.2-1 – Functional entities associated with network equipment based multi-path transmission

NOTE 1 – The details about functional entities and reference points are described in [ITU-T Y.2027].

NOTE 2 – The detailed descriptions of MPT mechanisms and capability requirements of MPT-enhanced functional entities in Figure A.2-1 are described in clause 7 and clause 8, respectively.

A.2.2 Scenarios

Based on the scenarios for MPT in [b-ITU-T Y-Sup.9], this annex identifies two possible scenarios with NE based MPT. In [b-ITU-T Y-Sup.9], the scenarios mainly described multi-connection user equipment (MUE). However, typical scenarios can also be derived, which can establish multiple connections between/among NEs with a conventional UE or MUE. Figure A.2-2 shows scenarios for NE based MPT. Based on the behaviour of the UE, two scenarios are identified.

One scenario is NE based MPT with ordinary UE, which is shown in Figure A.2-2(a), when an application of the UE uses a single path-based transmission. However, each NE (which works as MPT proxy with multi-connection control function and service control function (SCF)) located at the sender UE side provides multiple connections to the NE at the receiver UE side. For example, when users try to download their files in cloud storage with a certain degree of service level agreement based on IMT-2020 (5G) access network, network service providers can establish NE based multiple connections to support higher bandwidth and throughput for users.

The other scenario is NE based MPT with MPT-enhanced MUE, which is shown in Figure A.2-2(b). The MPT-enhanced MUE establishes a multi-path connection to support multiple flows of the applications of the MUE. In this case, NEs can also provide multi-path connections for each UE's network connection. For example, in multimedia streaming applications, video is transmitted by access network higher bandwidth (e.g., IMT-2020 or local wireless local area network) and text or voice are transmitted by 2G, 3G, or LTE to assure real-time service. At the same time, network service providers can establish NE based multiple connections to support various requirements for users (e.g., higher throughput, lower delay, etc.).

For both scenarios, some mechanisms are required to guarantee the aggregation of the service on the NE side. Cache and synchronization are the necessary mechanisms for aggregating sub-transmission flows.

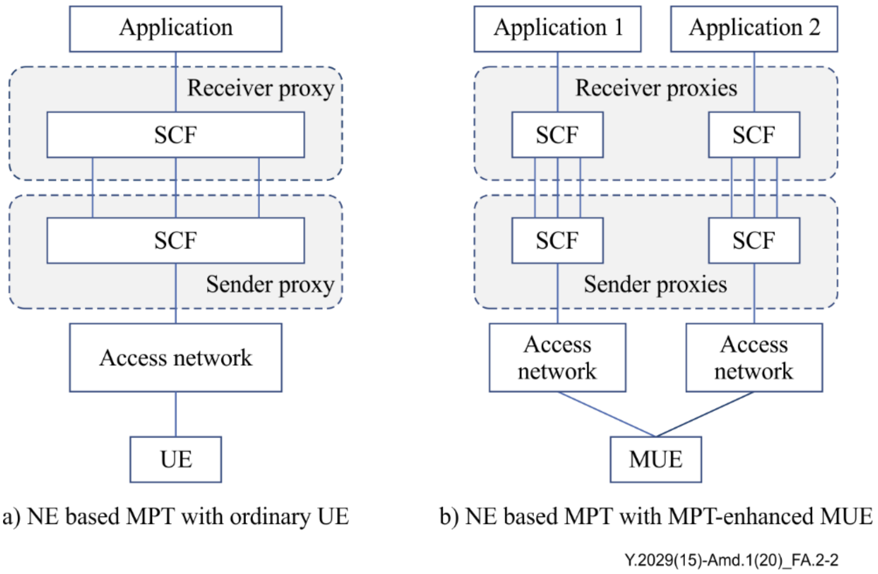

Figure A.2-2 – NE-based multi-connection scenarios

A.3 Information flow

A.3.1 Path selection mechanism for NE based MPT

A.3.1.1 NE based MPT with ordinary UE

The detailed information flow of an NE based MPT with ordinary UE scenario is shown in Figure A.3-1. This example supposes that UE_A and UE_B have no MPT functionality and multiple MPT-enhanced NEs exist (i.e., sender proxy and receiver proxy). UE_A tries to send heavy traffic to UE_B through MPT-enhanced NEs and NEs split the connection into several paths for network resource management.

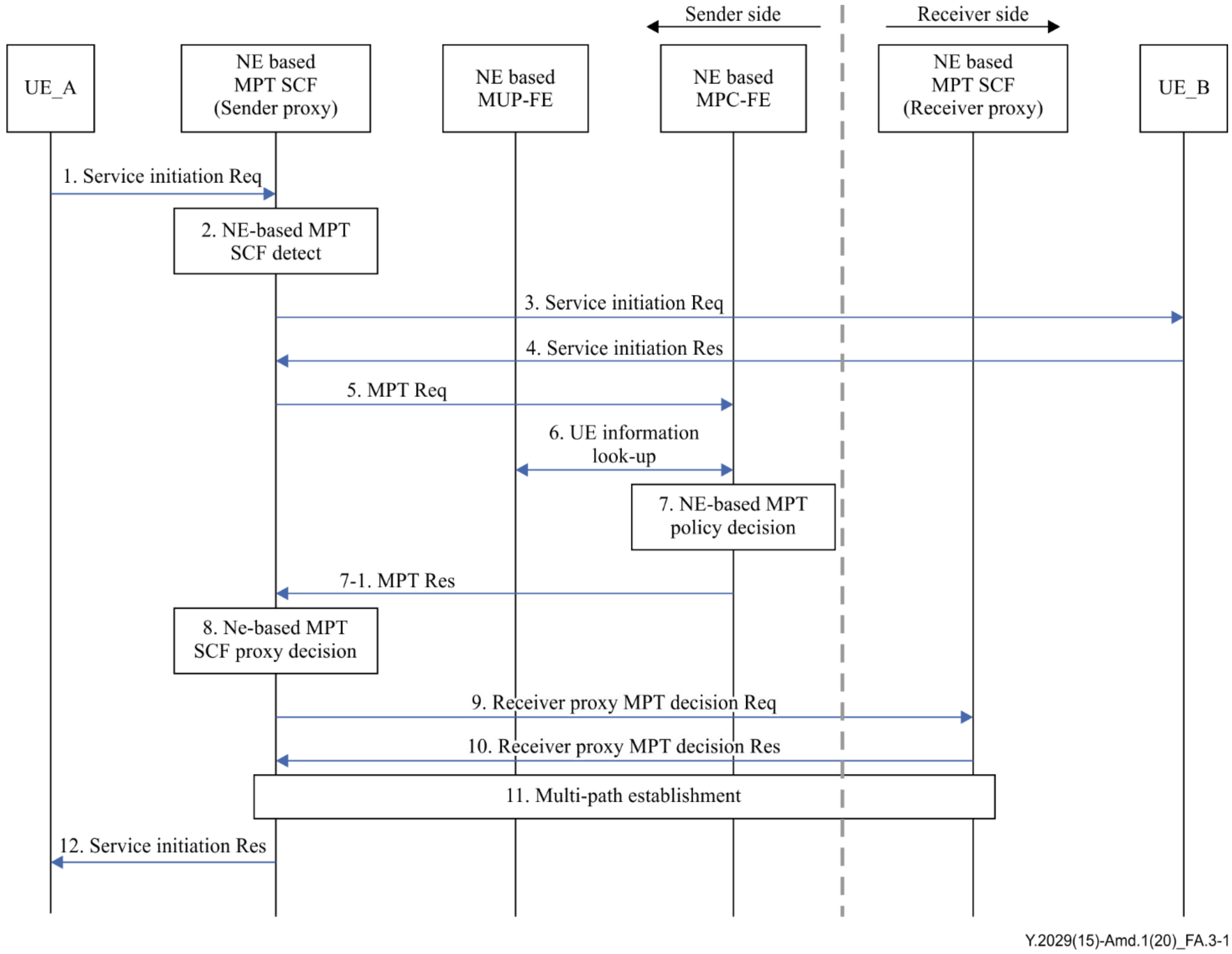

Figure A.3-1 – Path selection procedure initiated by network proxy with ordinary UEs

1) UE_A sends a service initiation request to UE_B,

2) A sender proxy (NE with MPT-enhanced SCF for UE_A) detects UE_A's connection establishment request,

3) The sender proxy sends a service initiation request to UE_B,

4) UE_B responds to the request from the sender proxy,

5) The sender proxy sends request from MPT to NE with MPT-enhanced MPC-FE,

6) After receiving the MPT request from the sender proxy, MPT-enhanced MPC-FE obtains the profile information from MUP-FE and judges whether MPT is possible or not,

7) MPT-enhanced MPC-FE makes MPT policy decisions and returns an MPT response message to the sender proxy indicating that UE_B has a dedicated NE (i.e., a receiver proxy),

NOTE – MPT policy decisions can be done by service level agreement between UEs and NEs.

8) The sender proxy decides whether NE supports MPT for UE_A or not,

9) If the sender proxy decides to perform MPT, it sends an MPT decision request to the receiver proxy,

10) The receiver proxy decides to use MPT and sends a response to the sender proxy,

11) After the establishment of the control connection, the sender proxy and the receiver proxy establish multiple data transmission paths,

12) The sender proxy responds to the UE_A's service initiation request.

A.3.1.2 NE based MPT with MUE

The detailed information flow of an example scenario of an NE based MPT with MUE is shown in Figure A.3-2. This example supposes that MUE_A and MUE_B have MPT functionality (i.e., MPT-enhanced MUE) and multiple MPT-enhanced NEs exist (i.e., sender proxy and receiver proxy). MUE_A tries to send traffics for multiple flows for the applications of the MUE to MUE_B through MPT-enhanced NEs and the NEs split each connection into several paths for network resource management.

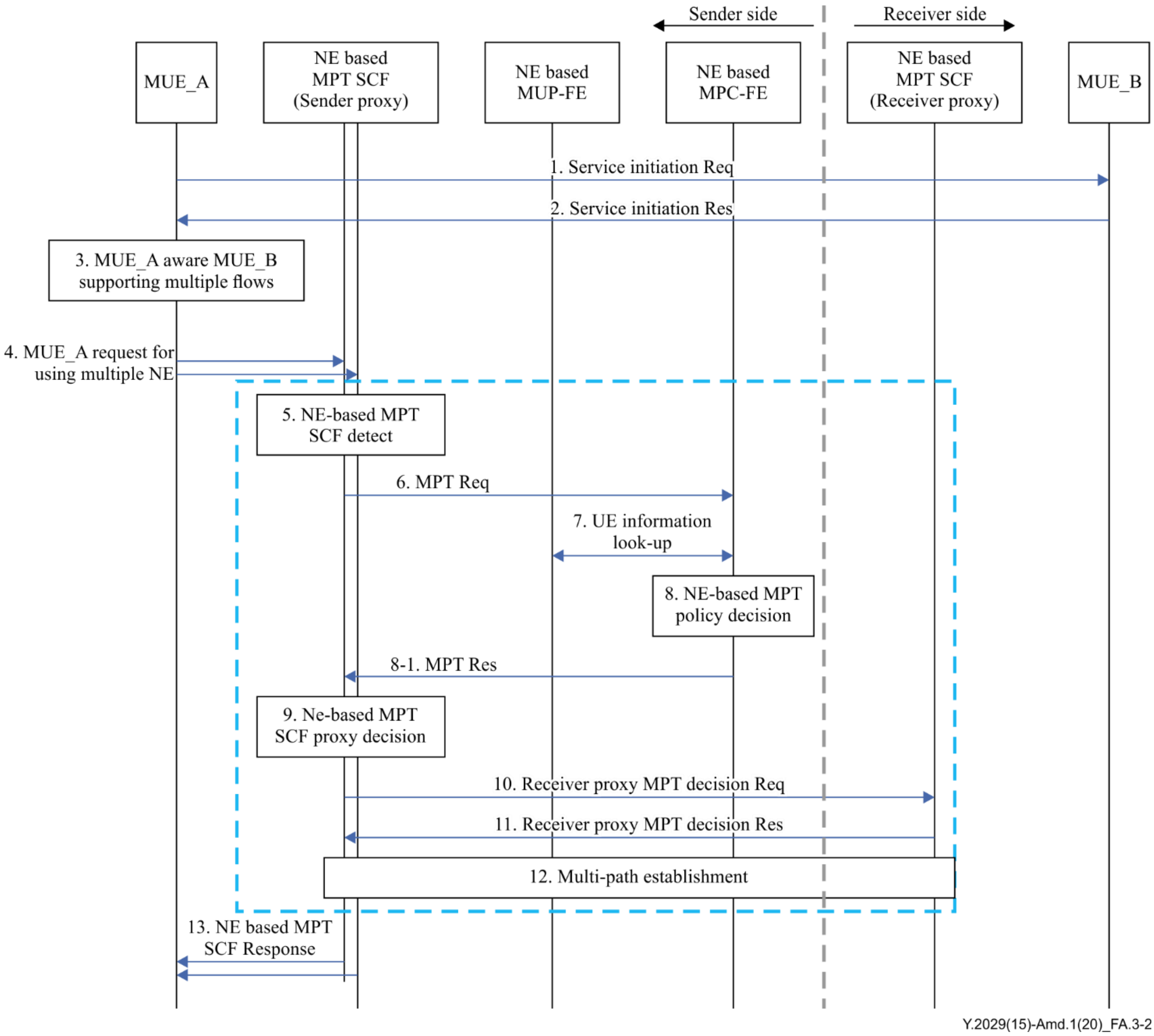

Figure A.3-2 – Path selection procedure initiated by network proxy with MPT-enhanced MUEs

1) MUE_A sends a service initiation request to MUE_B;

2) MUE_B sends a response to the service initiation request from MUE_A,

3) MPT-enhanced MUE_A is aware that MUE_B also has MPT-enhanced capabilities for supporting multiple applications,

4) MUE_A (MPT-enhanced MUE) sends request for connection establishment to each NE that can interact with each network interface of MUE_A,

5) A sender proxy (NE with MPT-enhanced SCF for MUE_A) detects a MUE_A's connection establishment request,

6) The sender proxy sends MPT request to MPT-enhanced MPC-FE,

7) After receiving the MPT request from the sender proxy, MPT-enhanced MPC-FE obtains the profile information from MUP-FE and judges whether MPT is possible or not,

8) MPT-enhanced MPC-FE makes MPT policy decisions and returns an MPT response message to the sender proxy indicating that MUE_B has a dedicated NE (i.e., a receiver proxy),

NOTE – MPT policy decisions can be done by service level agreement between UE and NE.

9) The sender proxy decides whether NE supports MPT for MUE_A or not,

10) If the sender proxy decides to perform MPT, it sends a MPT decision request to the receiver proxy,

11) The receiver proxy takes an MPT decision and replies to the sender proxy,

12) After the establishment of the control connection, the sender proxy and the receiver proxy establish multiple data transmission paths,

13) The sender proxy responds to the MUE_A's connection establishment for exchanging messages.

A.3.2 Traffic adjustment mechanism for NE based MPT

A.3.2.1 NE based MPT with ordinary UE

Figure A.3-3 shows the detailed information flow of an NE based MPT with ordinary UE. This example scenario supposes that UE_A and UE_B have no MPT functionality and NEs are MPT-enhanced (i.e., sender proxy and receiver proxy). UE_A tries to send heavy traffic to UE_B through MPT-enhanced NEs and NEs split the connection into several paths using MPT-enhanced SCF for timesaving and network resource management. After a period of time, a transmission path becomes congested due to the increased traffic load. The sender proxy would then adjust traffic transmission rate for sub-transmission flows based on the performance parameters of each flow. The traffic adjustment of each path is required to consider path conditions. At the same time, the packets transmitted by each path are required to be adjusted according to the available bandwidth and end-to-end delay of each path..

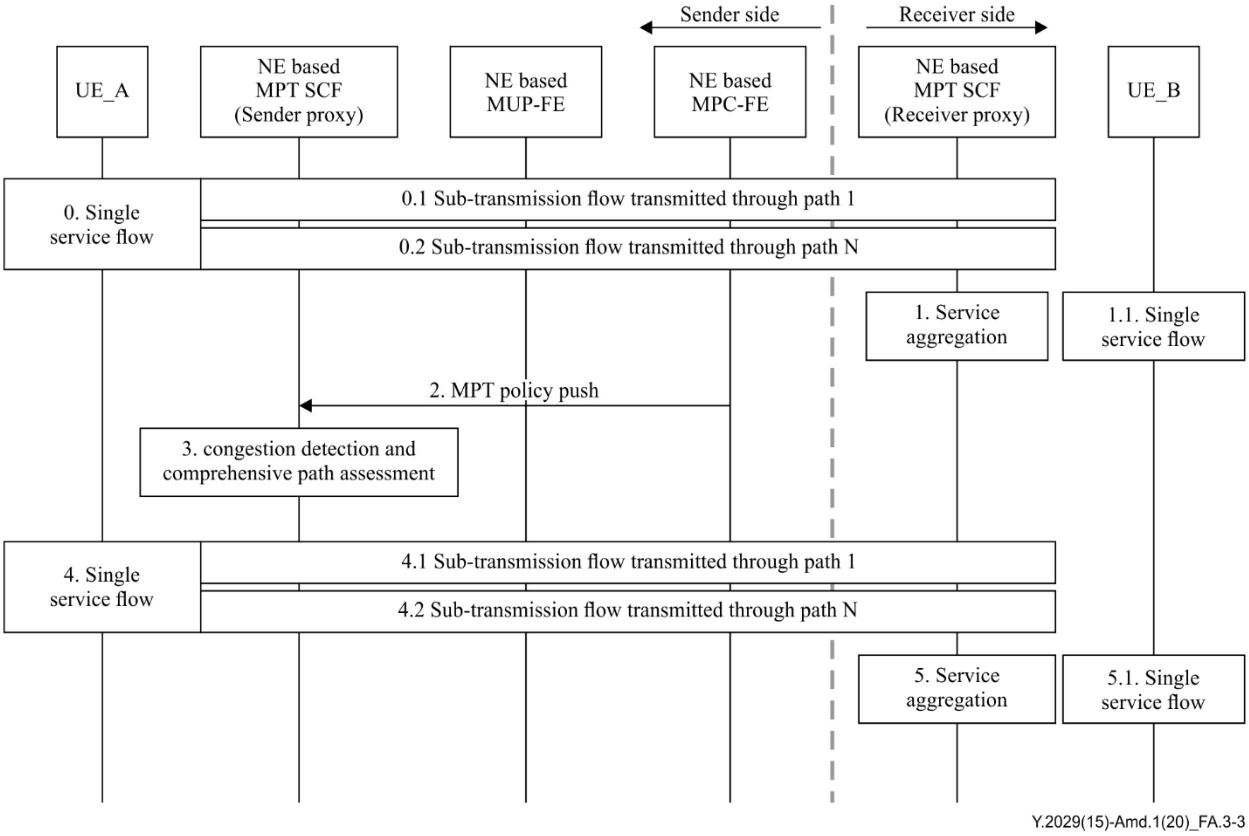

Figure A.3-3 – Traffic adjustment procedure by network proxy with ordinary UE

0) Data packets are transferred from UE_A to the sender proxy and the sender proxy splits a single service flow into multiple sub-transmission flow to the receiver proxy with MPT-enhanced SCF,

1) The receiver proxy aggregates service sub-transmission flows from the sender proxy and transfers to the destination UE_B,

2) MPC-FE collects and analyses networks' performance parameters, and periodically pushes them to the sender proxy with MPT-enhanced SCF as the traffic adjustment reference when necessary,

3) The sender proxy with MPT-enhanced SCF collects and analyses the path performance parameters of each sub-transmission path, and finds that a sub-transmission path becomes more congested than earlier,

4) Considering both path conditions and performances of each sub-transmission flow, the MPT-enhanced SCF adjusts the traffic transmission rate,

5) The receiver proxy aggregates changed service sub-transmission flows from the sender proxy and transfers to the destination UE_B.

A.3.2.2 NE based MPT with MUE

Figure A.3-4 shows the detailed information flow of an NE based MPT with MUE. This example scenario supposes that MUE_A and MUE_B have MPT functionalities (i.e., MPT-enhanced MUE) and multiple MPT-enhanced NE exists (i.e., sender proxy and receiver proxy). It considers the example scenario that MUE_A tries to send traffics of two different service flows through multiple access networks and each access network has designated NEs for handling NE-based MPT (the sender proxies). Similarly, MUE_B also receives traffics using multiple access networks with designated NEs (the receiver proxies). Each network proxy has MPT-enhanced SCF and designated MPT-enhanced MPC-FE for multi-path transmission. During the transmission, MPT-enhanced

MPC-FE may push network performance parameters for each proxies' sub-transmission flow as the traffic adjustment reference periodically.

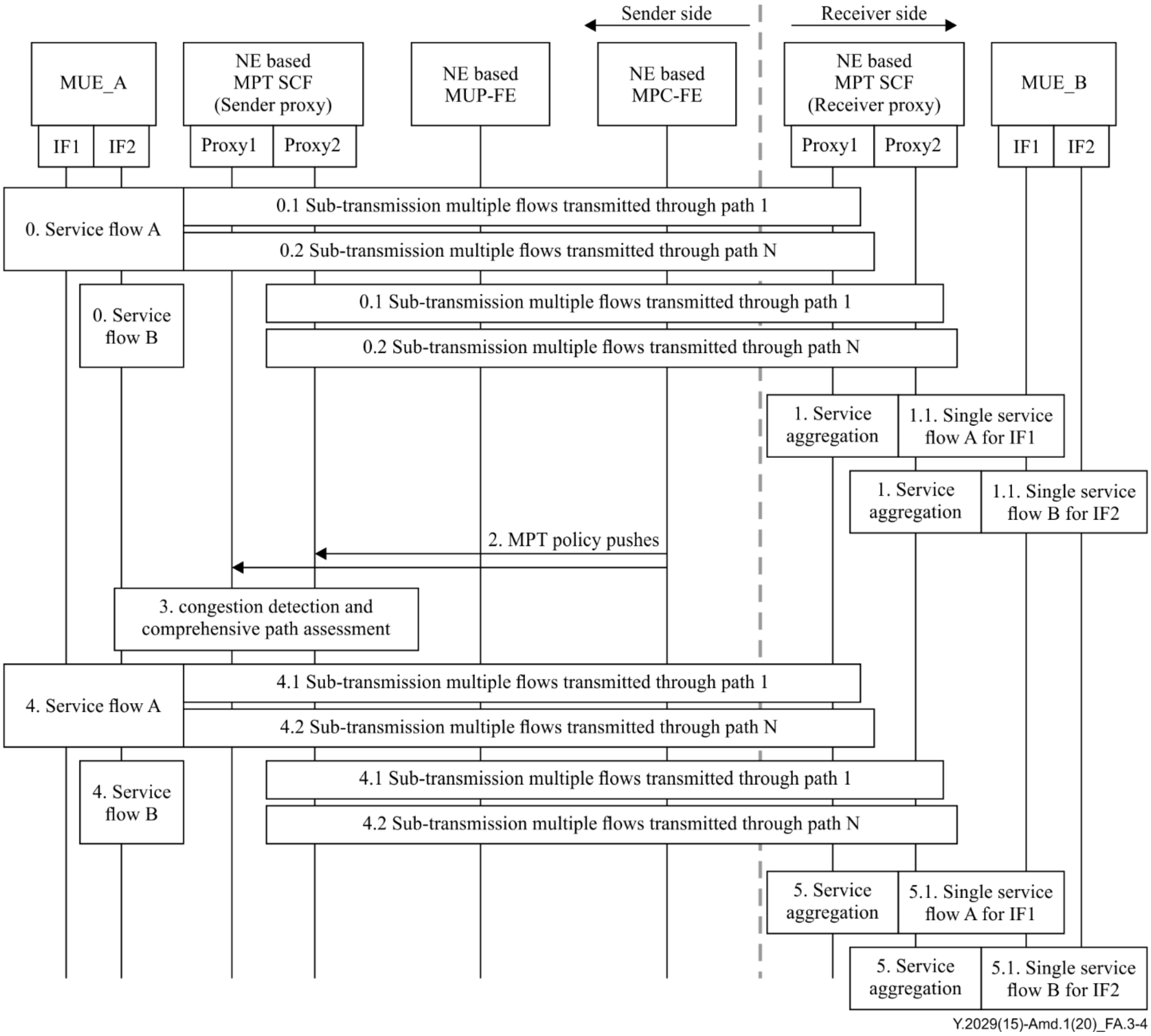

Figure A.3-4 – Traffic adjustment procedure by network proxy with MPT-enhanced MUE

0) Data packets of service flow A and service flow B are transferred through access network interfaces 1 and 2, respectively. Designated sender proxies for each access network split each service flow into several sub-transmission flows for NE-based MPT,

1) The receiver proxies aggregate sub-transmission flows from sender proxies as aggregated single service flows A and B and transfer them to the destination MUE_B through each access network interface,

2) MPT-FE collects and analyses the networks' performance parameters, and periodically pushes them to the sender proxies with MPT-enhanced SCF as the traffic adjustment reference when necessary,

3) The sender proxies with MPT-enhanced SCF collect and analyse the path performance parameters for each sub-transmission flow and they find that some path becomes more congested than earlier,

4) Considering both path conditions and performances of each path for sub-transmission flow, the sender proxies with MPT-enhanced SCF adjust the traffic transmission rate,

5) The receiver proxies aggregate changed service sub-transmission flows from the sender proxies and transfer to the destination MUE_B through each access network interface.

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