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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

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1 Scope

The present document proposes and analyses a traffic distribution architecture for hybrid access networks combining one or several terrestrial access technologies (fixed or mobile service) together with a satellite broadband access network (Fixed Satellite Service).

The traffic distribution architecture will enhance the end users' Quality of Experience by efficiently utilizing all available connections simultaneously using the Multipath TCP protocol. It allows for splitting traffic flows into smaller chunks, so-called objects, for which the most appropriated link is selected. The architecture is complemented by a Capacity and Link Status Estimation process that estimates link characteristics by passively monitoring TCP traffic, so that the Link Selection can be performed on a more informed basis.

The present document aims at:

- Defining the usage of the Multipath TCP protocol in Hybrid FSS satellite/terrestrial architecture.
- Proposing a method to split TCP traffic into connected chunks of traffic to ease the multipath routing.
- Proposing a routing scheme that distributes traffic intelligently among the available connections.
- Proposing a TCP-based link estimation method to passively determine available bandwidth and latency of a path.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 103 272: "Satellite Earth Stations and Systems (SES); Hybrid FSS satellite/terrestrial network architecture for high speed broadband access".

[i.2] IETF RFC 6824 (2013) (Ford A., Raiciu C., Handley M. & Bonaventure O.): "TCP Extensions for Multipath Operation with Multiple Addresses", (Experimental).

[i.3] EC FP7 Project: "Broadband Access Via Integrated Terrestrial & Satellite Systems (BATS)", D7.1 "Trial Evaluation", 2016/01/14.

[i.4] IETF RFC 3697: "IPv6 Flow Label Specification".

[i.5] IETF RFC 3917: "Requirements for IP Flow Information Export (IPFIX)".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

access link: link established between the IUG and the ING via a satellite or a terrestrial network

NOTE: One access link corresponds to one network interface.

application: program running on a device that requests or generates data that will form a Traffic Flow through a Network Interface

broadband access: access network where the downlink service rate is greater than or equal to 2 Mbps

high speed broadband: access network where the downlink service rate is greater or equal to 30 Mbps (Target set by the Digital Agenda for Europe)

hybrid access network: access networks combining a satellite component and a terrestrial component in parallel where the delivery of a service using both the satellite component and the terrestrial component intelligently to maximize the Quality of Experience for end users in under-served areas

Intelligent Network Gateway (ING): counterpart device of the IUG in an hybrid access network

Intelligent User Gateway (IUG): home device providing broadband access, security, cached storage capacity and QoE provisioning in a hybrid access network

network interface: interface that connects the IUG or ING to an access link

object: data unit created or requested by an application

Quality of Experience (QoE): subjective measure of the user's experiences with a service or an application (e.g. web browsing, phone call, TV, call to a Call Centre)

Quality of Service (QoS): objective measure of a service delivered by a network

service component: set of traffic flows resulting from an application including, where applicable, the various traffic flows requested by multiple functions within the application

traffic flows: sequence of packets sent from a particular source to a particular unicast, anycast, or multicast destination that the source desires to label as a flow

NOTE 1: More specifically it refers to a set of IP packets passing an observation point in the network during a certain time interval (see IETF RFC 3917 [i.5]).

NOTE 2: See IETF RFC 3697 [i.4].

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ADSL	Asymmetric Digital Subscriber Line
CAPEX	CAPital Expenditures
FSS	Fixed Satellite Service
GEO	GEOstationary satellite
IAT	Inter-Arrival Time
IAT-ING-InterObj	IAT-ING-Inter object
IAT-ING-IntraObj	IAT-ING-Intra object
IAT-ING-Thresh	IAT-ING-Inter Threshold
IAT-IUG-InterObj	IAT-IUG-Inter object
IAT-IUG-IntraObj	IAT-IUG-Intra object
IAT-IUG-Thresh	IAT-IUG-Inter Threshold

IDU	InDoor unit (or modem)
IETF	Internet Engineering Task Force
ING	Intelligent Network Gateway
IP	Internet Protocol
IUG	Intelligent User Gateway
LAN	Local Area Network
LEO	Low Earth Orbit (satellite)
LTE	Long Term Evolution
MP	Management Point
MPTCP	MultiPath TCP
NAT	Network Address Translation
OPEX	OPerational EXpenditures
PSBOL	Path Selection Based on Object Length
QoE	Quality of Experience
QoS	Quality of Service
RFC	Request For Comment (IETF document)
RTT	Round Trip Time
SSH	Secure SHell protocol
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VPN	Virtual Private Network
WAN	Wide Area Network
WRR	Weighted Round Robin

4 Hybrid access network with heterogeneous links

4.1 Architecture overview

The present document assumes a hybrid access network delivering High speed broadband service such as the one depicted in Figure 1. The concepts and rational for this as well as further details are defined in ETSI TR 103 272 [i.1].

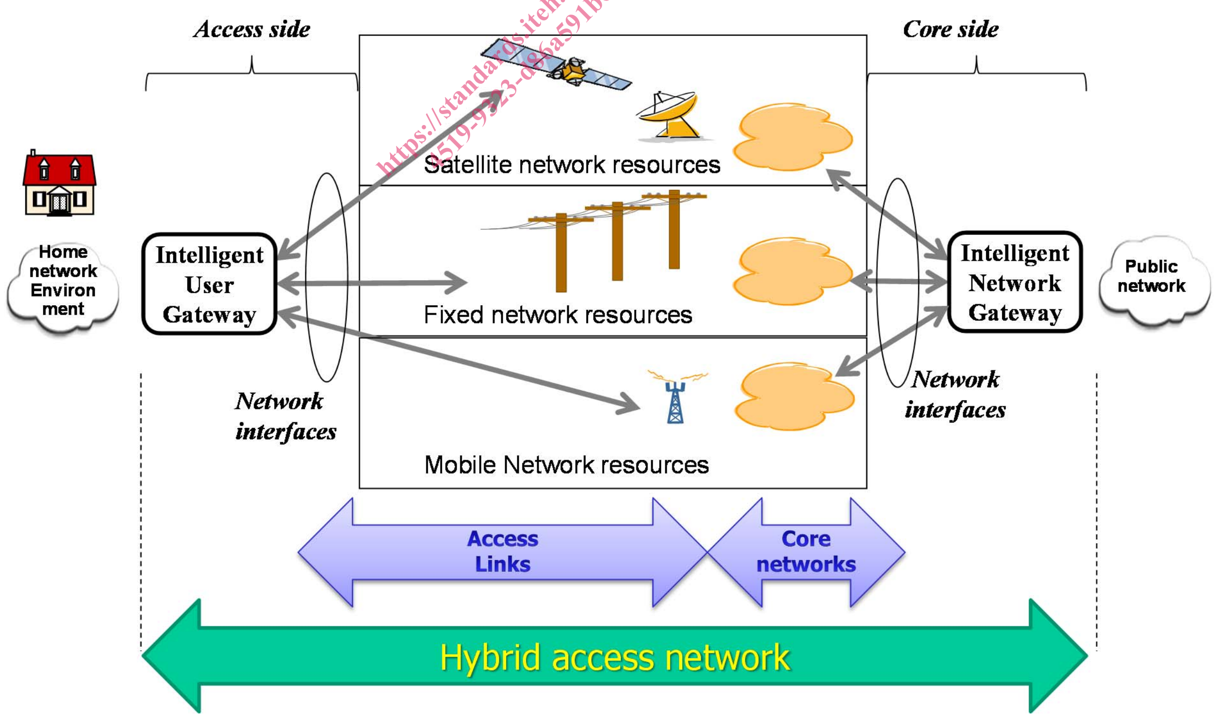

Figure 1: Hybrid access network architecture

4.2 IUG and ING functional architecture

The present document focuses on defining the key building blocks in both Intelligent User Gateway (IUG) and Intelligent Network Gateway (ING), which are the link estimation, the traffic splitting component and the link selection, as shown in Figure 2. The first is responsible for determining the characteristics of all available paths between the IUG and the ING, while the second splits the incoming traffic flows from the Home network environment or the public network, respectively, into smaller chunks of traffic, so-called objects. It is then the responsibility of the link selection component to distribute these chunks onto the available links based on their characteristics.

It should be noted the predominant traffic expected in this kind of hybrid access network is TCP/IP traffic. Hence, the present document focuses on optimizing TCP traffic handled in a hybrid FSS satellite terrestrial network. How other traffic is being handled is largely out of scope of the present document, although UDP handling is discussed in clause 5, as a proposal. Regular routing methods needs to be in place, which work independently of the mechanisms presented in the present document. The architecture in the present document neither harms nor optimizes the handling of non-TCP traffic.

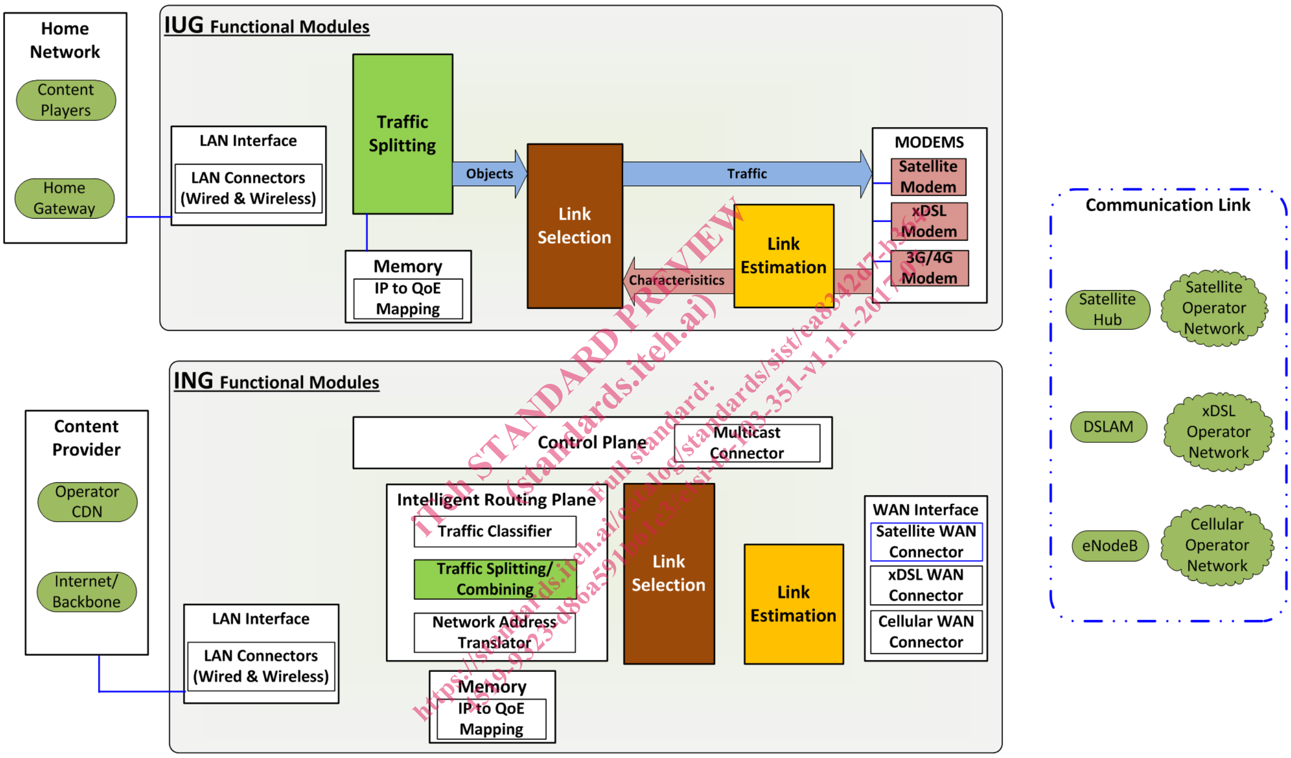

Figure 2: Key building blocks in IUG and ING

5 Multi link routing with traffic dichotomy

5.1 Introduction

In its current version, the Multi-Link Architecture relies on:

- A traffic Classification or "traffic dichotomy" between TCP traffic and non TCP traffic (such as UDP traffic).
- Multipath-TCP (MPTCP) [i.2] as its basic multipath technology between the IUG and the ING, to efficiently exploit the multiple paths between the IUG and ING. Hence, MPTCP is not used end-to-end. Instead, a MPTCP proxy is running on the IUG and ING, which breaks the TCP end-to-end paradigm. The connection from the client to the server is intercepted by the MPTCP proxies on the IUG and the ING, so that a single TCP connection can be split into three (MP)TCP connection, namely between end host and IUG, IUG and ING, where MPTCP is used, and ING and the other end host of the connection.

Between those two MPTCP proxies, tunnels are established in order to operate independently of the underlying networks. Between the end systems and the IUG or ING, respectively, regular TCP will be used.

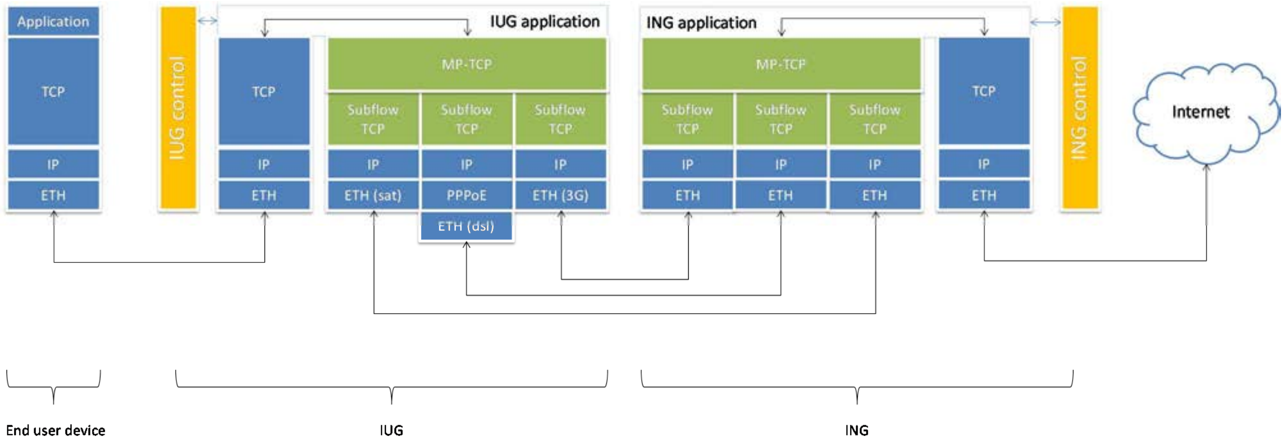

Figure 3: MPTCP proxy architecture

As depicted in Figure 3, between IUG and ING multiple MPTCP subflows are established. To be precise, the MPTCP proxy on the IUG creates for each TCP flow as many subflows as there are different Physical or Logical links available on the IUG side. In Figure 3 it can be seen that 3 logical links available on the IUG: One ADSL link thru a native ADSL physical interface, one Satellite link accessible thru an external IDU via a physical Ethernet interface and one 3G/4G Link accessible thru an external modem via the same or another physical Ethernet interface. The IUG and ING control are responsible for link estimation, link selection and traffic splitting to each TCP subflow. Hence, the link selection process running on IUG and ING needs to distribute the traffic on the available subflows.

It is important to note that the MPTCP standard [i.2] does not specify how the traffic is distributed among the available subflows.

5.2 TCP traffic splitting and recombining plus UDP traffic forwarding

5.2.1 Overview

For TCP traffic, the Link Selection operates on TCP objects. An object is a sequence of TCP segments belonging to the same flow, i.e. same source and destination IP and same source and destination port, which are sent within a given time frame. Figure 4 below gives an overview of the algorithm. As indicated long objects are routed over the highest bandwidth link available while short objects are routed over the link with the lowest RTT.

The Link for UDP Traffic may be selected as the one minimizing a link cost function, defined as a combination of weighted criteria such as Link Reliability, One Way Maximum Latency, Available Bandwidth, Bandwidth cost and OPEX/CAPEX considerations. The criteria and their weight should be configurable, in order to provide a flexible deployment for operator's needs. In a 1st approach, the One Way Maximum Latency may be measured or estimated per Access Network (ADSL, Cellular and Satellite), and this performance estimation could be provisioned as input of the link selection for UDP traffic.

Additionally, the traffic - TCP and UDP - may be split into critical and not critical traffic. The critical traffic may be routed towards the links that have the highest reliability, in terms of 'service continuity' or 'link availability along time'. In this case, the weights of the combined criteria have to be changed:

- Critical applications based on TCP would use reliable links as main criteria, if such links are available. These links are associated to MPTCP subflows.
- Critical application based on UDP would use reliable links (as main criteria), selected amongst ADSL, Cellular, Satellite reliable links. In this case, these links are not associated to MPTCP subflows. It does not prevent from using other secondary criteria, such as OneWay Maximum Latency and/or Available Bandwidth.

The algorithm described in Figure 4 handles Link selection for both TCP and UDP traffics and is given as an example:

- It only handles Bandwidth and RTT criteria for TCP traffic.
- It assumes that the ADSL Link has a lower cost than the Cellular Link, which is less expensive than the Satellite link. Moreover, the same route is selected for all the UDP traffic.

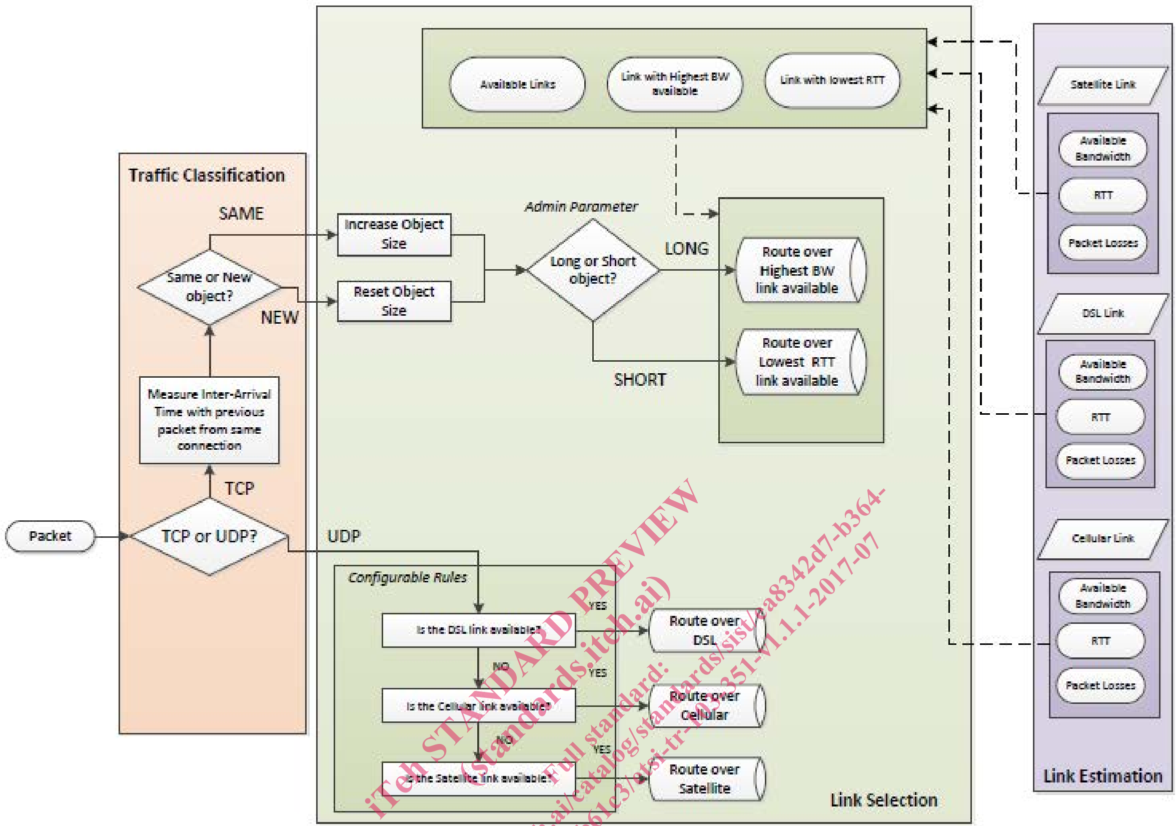

Figure 4: Algorithm Flow Chart

5.2.2 Concept of a TCP object

A typical client-server dialog is depicted in Figure 5. A client sends an object O1 to a server that replies with an object O2, then the client sends an object O3 to the server and receives an object O4.