# TCP Level Aggregated Communication over Heterogeneous Access Networks

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## I. Introduction

With the evolution of the mobile devices, enabling them to connect to multiple radio technologies and to simultaneously communicate over the afferent access networks at high throughput rates, a real opportunity in deploying efficient multi-homed data exchange is foreseen.

The deployment of novel radio technologies such as LTE, additionally to the already available access networks such as 2G/3G-3GPP and non-3GPP accesses (e.g. WiFi, HRPD, WiMAX), enable the network operators to offer multi-homed connectivity to a large number of devices with customized costs depending on the specific momentary services used, on the available resources in the operator network and on the subscriber and operator preferences.

However, the current solutions for multi-homed devices such as Multi-Path TCP ([1]), mobile SCTP ([5]) and the Host Identity Protocol (HIP) ([7]) are mainly concerned with end-to-end signaling, thus requiring the correspondent nodes to be extended with specific functionality related to the respective protocol, which is a major impediment for deployment in carrier grade operator networks in the next time interval.

This presentation describes a solution for realizing such functionality by extending only the multi-homed user devices and by introducing a specific functionality in the operator core network. Our solution enables communication over multiple interfaces to remain transparent to the corresponding parties while maintaining the advantages obtained by aggregating multiple heterogeneous radio carriers such as the dynamic increase of the throughput for specific applications through the aggregation of multiple data flows.

Additionally, through the integration of the proposed solution in the operator core network, a new level of QoS can be obtained for specific data flows which, apart from the throughput improvement, also allows differentiated latency, jitter and packet loss characteristics, specific to the alternative access technologies used. This feature enables the applications to receive differentiated QoS over the multiple accesses while not influencing the already established communication services.

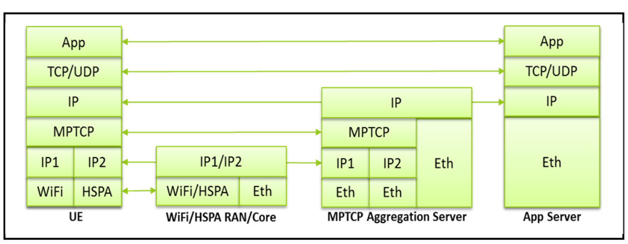


Figure 1 - Solution User Plane Protocol Stacks

The presentation includes also a possible migration path from the current operator network towards the support of aggregated communication over heterogeneous access networks. On the third part, the presentation describes in detail the testbed which enables the evaluation of the solution, as well as the next steps considered for further expanding the concept and its testbed practical realization.

## II. Solution

In order to be able to aggregate the communication of the mobile devices over multiple access technologies in a transparent manner for the intermediary data forwarding entities and for the corresponding nodes, the proposed solution considers that the multi-path communication has to be executed only between the mobile device, here denoted User Equipment (UE) and a network aggregation server.

For the handling of the multiple data paths available to the mobile device, the Multi-Path TCP (MPTCP) protocol is considered, as it permits rapid deployment over current network infrastructures in which only TCP and UDP and limited ICMP data packets are allowed to pass network firewalls.

In order to maintain the communication of the mobile device

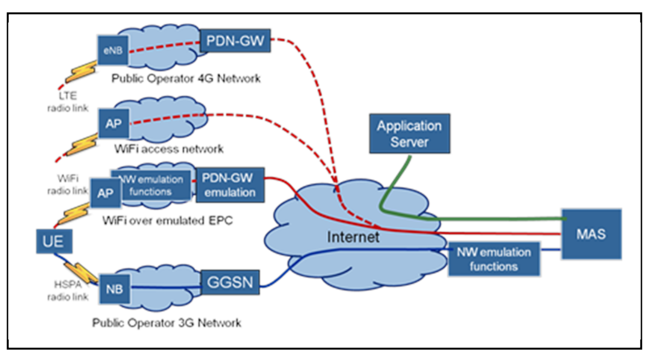


Figure 2 – Testbed Architecture

transparent to the correspondent nodes regardless of the multiple data paths, on top of the MPTCP an end-to-end IP communication is considered, as depicted in Figure 1. Through this means, the role of the MPTCP is changed from a protocol which enables end-to-end multipath connectivity to a link-layer transport protocol enabling the harmonized simultaneous usage of multiple data paths through the operator network.

Considering that the device receives two distinct IP addresses when attaching to the two access networks, for example IP1 over WiFi and IP2 over HSPA, when it requires to communicate with a specific correspondent node using either one of these IP addresses or an IP address uniquely allocated to the mobile device, a TCP connection is established between the UE and the MPTCP Aggregation Server (MAS).

When the communication requires aggregation of multiple accesses, the second TCP connection is established to the MAS. The MPTCP functionality in both the UE and the MAS will handle the IP data traffic of the device as application level content of the MPTCP connection. Additionally, the nodes treat the MPTCP connection as a link-layer transport protocol enabling the forwarding of the data packets to the UE applications respectively towards the correspondent nodes.

## III. MIGRATION PATH

In order to deploy such a solution in the current mobile operator core network, the following additions have to be brought to the communication functionality.

First, the MPTCP stack has to be introduced in the UEs capable of aggregated multi-homed communication. Through this layer all the IP data packets of the device are exchanged with the novel MPTCP Aggregation Server (MAS).

The MAS function is able to handle the MPTCP as a link-layer connection of the mobile device. For the downlink it presumes the forwarding of all the data packets received for the IP address of the device encapsulated into MPTCP packets. For the uplink, it presumes the decapsulation of the MPTCP packets received from the device and their forwarding towards the correspondent application servers.

From the perspective of legacy devices, this functionality remains transparent, thus enabling the operator the gradual deployment of MAS functionality in the network depending on the available UEs.

However, in case of the multi-homed devices which connect through the MAS, even when a single access network is used possible impact of the MPTCP implementation on performance has to be further investigated, as an intermediary TCP stack is introduced.

## IV. TESTBED DESCRIPTION

In order to evaluate the potential and behavior of the MPTCP carrier aggregation solution, a testbed environment is considered as depicted in Figure 2. In a first phase, the testbed environment consists of two access networks: an HSPA connection through a public operator network and an WiFi connection emulating the LTE access supported by an emulated Evolved Packet Core (EPC) core network architecture ([3], [4]), enabling the IP address allocation and the establishment of a data path. As the UE has to be able to reach the MAS using the public HSPA connectivity, an additional VPN tunnel is included enabling the device to communicate with the other testbed components.

Because it is expected that the throughput available for the UE through the WiFi access network in laboratory environment is larger than the capacity offered to a single user through operator deployed wide-area LTE access networks, a network emulation function is deployed as part of the EPC emulation, enabling the throttling of capacity according to different evaluation scenarios.

The same functionality is also deployed over the HSPA link between the UE and the MAS, however closer to the MAS, as the testbed cannot control the HSPA link of a public network.

For testing the effects of the solution on different data flows a multimedia application is deployed on both the mobile device and on an application server.

Additional WiFi access networks or public LTE can be added to the testbed in a later phase in order to enable more complex evaluation scenarios.

## V. SUMMARY AND FURTHER WORK

In this presentation a novel solution using MPTCP as link-layer transport was presented including both a high level view of the operations, the identified components that have to be further extended from current operator networks and an initial testbed realization enabling the evaluation of the proposed solution.

As immediate further work, a set of application scenarios will be evaluated on the testbed described here. The evaluation presumes the usage of a single and of an aggregated connectivity for both time constraint and bulk data traffic using either TCP or UDP as end-to-end transport protocol.

Provided the initial results achieved in the present testbed are satisfactory, on a longer perspective, the solution will be integrated as part of the Fraunhofer OpenEPC software core network realization ([6]).

Additionally, the OpenEPC testbeds will be coupled with LTE and HSPA access networks enabling the re-evaluation of the testbed when the complete operator functionality is available.

## VI. REFERENCES


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