Multilink solution for 5G: Efficiency Experimental Studies

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***Abstract* — 5G-Xcast is a project focused on Broadcast and Multicast Communication Enablers For the Fifth Generation of Wireless Systems. Within the project for the most number of defined use cases it is necessary to provide adequate throughput, delay, reliability, seamless handover etc. For this purpose multilink approach can be used. This paper describes multilink benefits, its high-level description and implementation to the 5G core architecture for better user experience. Also was described the methodology of the experimental studies to estimate the effectiveness of the proposed solutions. The experiments were conducted in the IRT testbed (Munich) and have shown great increase of the overall QoE.**

Keywords—5G, 5G-Xcast, bonding, multi-connectivity, multilink, experiment, bonding

I. INTRODUCTION TO 5G-XCAST PROJECT

5G-Xcast is a 5GPPP Phase II project focused on Broadcast and Multicast Communication Enablers For the Fifth Generation of Wireless Systems **[**1**]**. The main objective of the project is to design a dynamically adaptable 5G network architecture enabling seamlessly switching between different modes (unicast, multicast and broadcast) depending on the conditions to provide unprecedented opportunity for the future media delivery with the best quality of user experience. There were identified uses cases relevant for the project, including use cases relating to M&E [1, 2]. For these use cases it is necessary to provide adequate throughput, delay and reliability. For this purpose multilink technologies can be used.

II. THE HYBRID BROADCASTING SERVICES

The Hybrid Broadcasting Service (HBS) is conceived as the combination of linear and non-linear audiovisual content plus other attractive features such as social media and/or interactivity, which are made available to enrich user experience with personalized content. Access to content and services is enabled on different user devices and in different environments, from venues to large geographical areas, via content delivery over a combination of several networks, even simultaneously.

The realization of the HBS involves the fulfillment of multiple requirements which the 5G-Xcast solution shall provide. Amongst others, user devices shall be able to automatically connect to the best available networks in terms of quality of experience (QoE). Network resources should adapt to the audience size and geographic area to be served minimizing distribution costs and enabling that, when using multiple networks, it should be possible to offload the traffic among them (e.g. fixed, mobile and/or broadcast networks). Content delivery should use multiple networks at the same time and switch among networks including when operated by different operators, supporting the dynamic optimization of resource allocation by automatic switching among unicast, multicast and broadcast. The transition among unicast and broadcast and multicast should be allowed during service, without impact on viewers and other users, and within a minimized transition time (in the order of seconds). The 5G-Xcast solution should be able to provide a sufficient data rate to deliver audiovisual content up to ultra-high definition (UHD) quality while minimizing end-to-end latency and managing difference in delay between different streams on the same device.

The HBS may provide numerous benefits to the main actors in the M&E value chain. Users may benefit from the continuity of the experience when switching between networks enabling seamless access to audio-visual content both at home and on the move. Content and service providers benefit from the delivery of content to a wide range of user devices over the 5G infrastructure with reduced complexity and cost. From the network side, operators can benefit from a more efficient use of network resources and topologies to enhance cost efficiency of content delivery.

III. MULTILINK TECHNOLOGY OVERVIEW

Multi-connectivity supports simultaneous connectivity and aggregation across different technologies such as 5G, LTE, and unlicensed technologies such as IEEE 802.11 (Wi-Fi) [3].

In heterogeneous networks, multi-connectivity helps to provide an optimal user experience (e.g. high bandwidth, network coverage, reliable mobility etc.). One subcase of multi-connectivity is multilink.

In this paper multilink (ML) is the exploitation of different heterogeneous wireless link for improving service delivery.

In the scenarios that require high bandwidth or assured service continuity, a user may need multiple concurrent connections. For example, data aggregation from multiple subscriptions to LTE, 3G and Wi-Fi (and even fixed networks) increases available bandwidth. A cellular (e.g. 5G or LTE) network access is required to maintain the service continuity after a UE has access to Wi-Fi coverage.

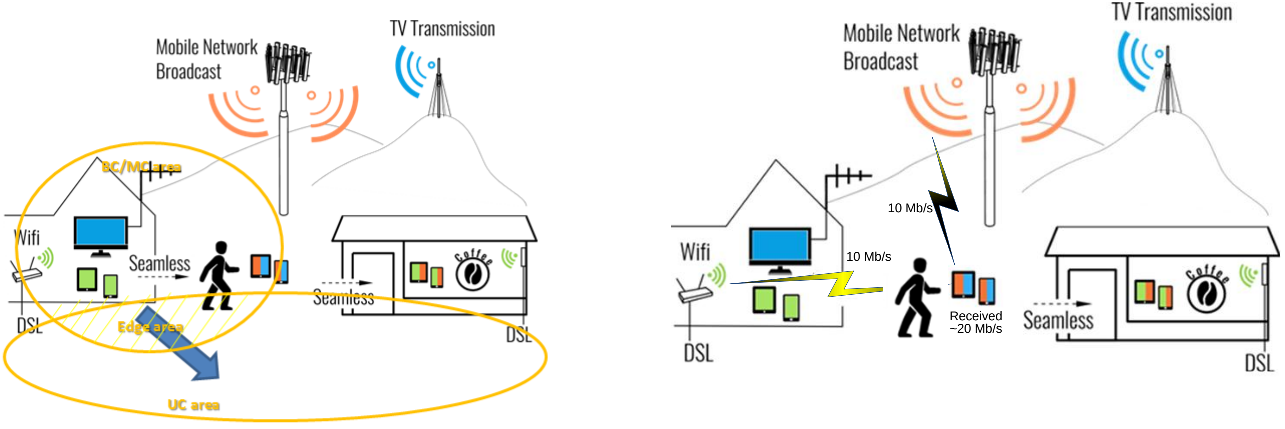
IV. BACKGROWND WORK

In previous papers were described some widespread and well-known multi-connectivity technologies, such as Dual connectivity (DC) [5], LTE-WLAN Aggregation (LWA) [6], RAN-Controlled LTE-WLAN Interworking (RCLWI) [7], LTE-WLAN Radio Level Integration with IPsec Tunnel (LWIP) [8]. Some sources are devoted to the proprietary ML protocols and implementation scenarios description (LU, Samsung etc.)

But in this paper we will focus on the possibility to implement ML into the 5it G core architecture to provide better QoE for the subscribers, especially on experimental studies of multilink.

V. PROBLEM STATEMENT

Within the 5G-Xcast project there were identified main use cases for multilink usage. The first, mobile device (user equipment (UE)) is on the edge of the broadcast/multicast (BC/MC) area (Fig. 1a), and the second, when UE needs increased channel bandwidth for best possible QoE (Fig. 1b).



(a)

(b)

Fig. 1. Multilink implementation:
(a) – on the edge of the MC/BC and UC areas
(b) – when the UE needs increased bandwidth

For the use cases (Fig. 1) the user can generate a full quality and reliable video only if he receives data via several available wireless channels. It allows the user to get the video in the best quality, seamless and quick transition between MC and UC areas.

Looking on the possible benefits from ML usage, it was decided to implement ML entities into the 5G core architecture and to develop necessary procedures for this ML approach. But the first step is to ensure the efficiency of proposed approach for the converged networks on practice.

VI. MOBILE CORE ARCHITECTURE WITH MULTILINK

A. *Multilink implementation to the 5G-Xcast architecture*

There are two main agreed alternatives of 5G-Xcast architecture. These alternatives were developed to realize the 5G converged core network, which will be able to provide novel broadcast/multicast services for the users.

The following is a description of how the multilink gateway (MLGW) can be integrated into the 5G mobile core architecture (Fig. 2).

An example of data transition with ML can be described as follows. There is one common data stream from the Content Server, which is transferred to MLGW. It duplicates data flow between (R)AN and non-3GPP access. After reception in the Converged middleware, the split data is combined by the multilink middleware (ML-MW) into one common stream. To ensure that this approach is good on practice it was decided to provide its experimental studies.

VII. ML SOLUTION EXPERIMENTAL STUDIES

A. *Testbed Description and Measurement Setup*

The IRT test facilities in Munich implement an LTE eMBMS network with a base station serving four sites via remote radio heads (RRHs). The sites are located in the surrounding of Munich, covering a wide part of its urban area. The inter-site distances are in the range between 1.8 and 19.8 km, that permit configuring the Multicast Broadcast Single Frequency Network (MBSFN) with a CP 16.67 µs, providing enough coverage for testing purposes. The sites are operated in LTE band 28 (FDD, 706 to 716 MHz uplink, 761 to 771 MHz downlink). The transmit power of the network is 400 W effective isotropic radiated power (EIRP) per site/antenna. The transmit signal is a combination of 60% capacity for broadcast (MBSFN subframes) and 40% for regular unicast traffic.

Multi-link is tested by means of an external unit (provided by LiveU) that is able to bond the traffic from different interfaces. The unit is connected to an entity in the cloud in charge of splitting the original source and route the traffic to the client. At the client side, the unit is connected via ethernet to a laptop that will request the reception of traffic.

The performance of multi-link with unicast traffic over the LTE (700 MHz) and WiFi (2.4 GHz) networks is analysed by means of monitoring different network interfaces (i.e. the upcoming traffic to the PDN Gateway from the internet, the ethernet link between the LiveU unit and a laptop, and the interface of a WiFi AP where the unit is attached). An H.264 test video stored in a CDN server is used as the source for monitoring IP traffic. The video is a variable bit rate clip with an average data rate of 3.77 Mbps. The playback is triggered by a video player at the client laptop.

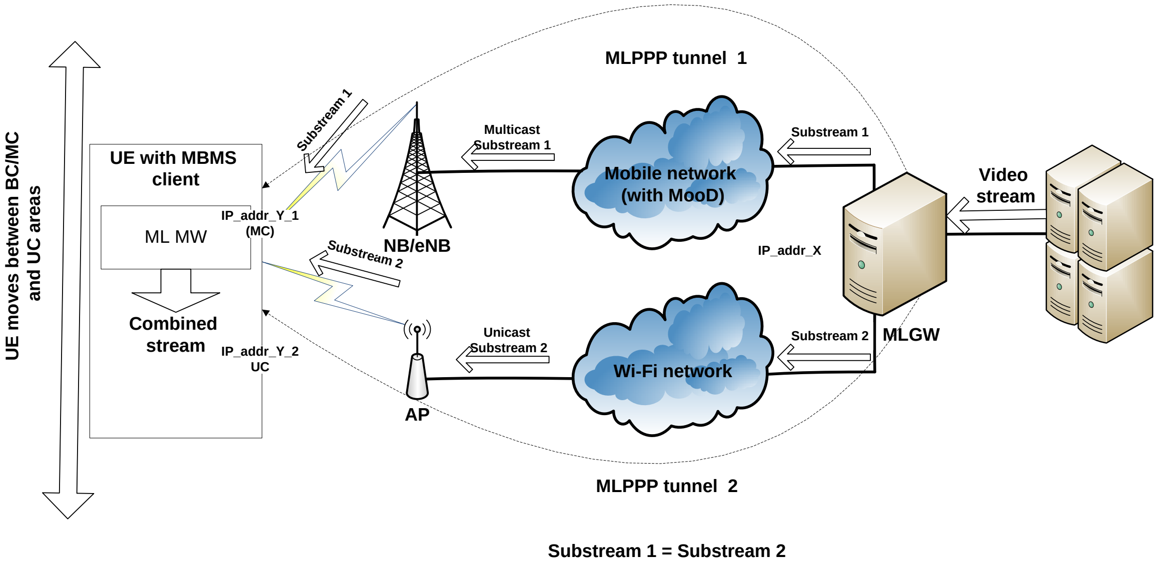
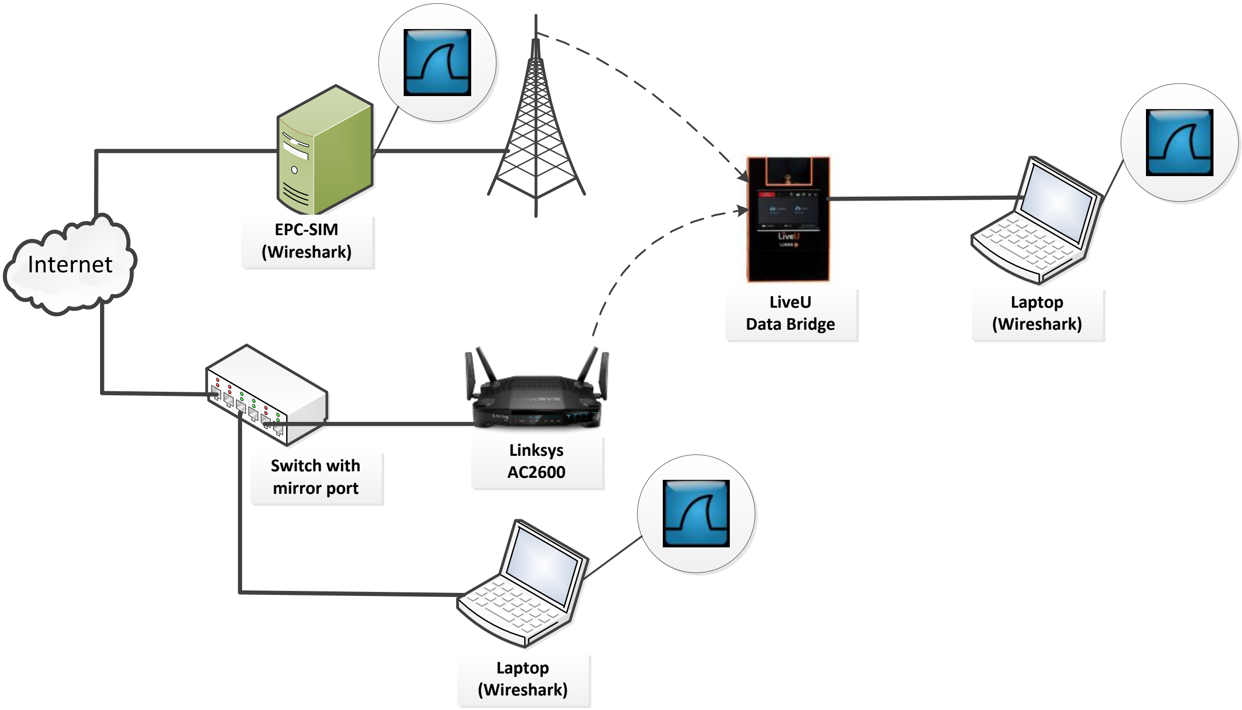


Fig. 2. MLGW integration with mobile core architecture

A set of test measurements are taken at the premises of the IRT. A transition scenario between an indoor area with WiFi but poor LTE coverage and an outdoor location without WiFi but good LTE coverage is selected. The AP is mounted close to a window in order to obtain a smooth WiFi coverage decrease when transiting to the outdoor location. It should be noted that it is desirable that the network details are stored in advanced in the ML unit and the interfaces active so that in the presence of signal coverage the connection can be established inmediately. An overview of the scenario and the route followed in the measurements can be seen in Figure 3.



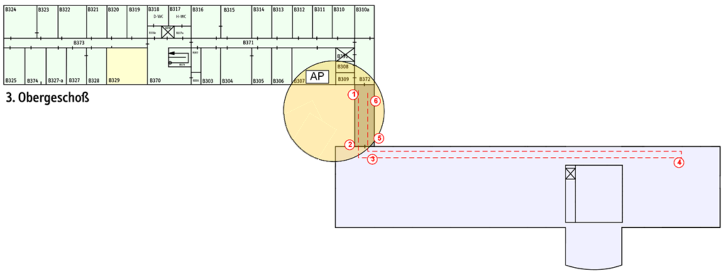


Figure 3. Munich Hybrid BB-BC Multilink Architechture – Setup1

B. *Experimental Results*

Figure 4 shows the results of measurements along the route. The instantaneous throughput (bps) as a function of time is represented for the three monitored interfaces. The line in violet is the IP traffic between the LiveU unit and the client laptop. The red and green lines represent the traffic at the WiFi AP and the LTE ePC, respectively.

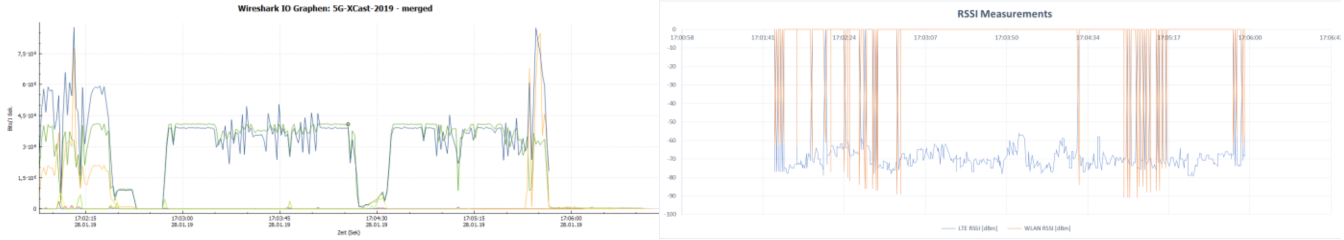


Figure 4. The results of measurements along the route

It can be seen that the traffic sent to the laptop when both the WiFi and LTE network provide good coverage is the aggregated throughout by the LiveU unit. In the transition area where WiFi coverage is lost (see the decay of the red line) only traffic from the LTE network is received, with the same bitrate as the original video source what translates into no disruption at the client. When the WiFi connection is restored, the traffic is, again bonded. It should be noted that during the experimental testing, the video was presented at the laptop without any disruption. By taking a closer look into the TCP traffic at the LiveU unit to laptop connection it is possible to detect the reception of several TCP Retransmissions, TCP DupACK´s, TCP Fast Retransmissions and TCP Spurious Retransmissions that indicate the presence of an error-free mechanism to prevent packet losses. Table 1 collects the statistics of the video client at the laptop during the experiment.

Table 1

Video Statistics	
Decoded	14378 Blocks
Reproduced	7161 Frames
Lost	0 Frames
Input Bitrate	5635 kb/s
Data Bitrate	2516 kb/s
Lost Bitrate	0

CONCLUSIONS

This paper analyzes different requirements for broadcast/multicast delivery within 5G-Xcast project. To meet these requirements it is necessary to use multi-connectivity as a key technology. One of the possible solutions is multilink. The main use case for the seamless transition between different areas (multicast/broadcast and unicast) was described as an example. To provide ML functionality it is necessary to include additional features to several 5G NFs. That is under the current study. But to ensure the possibilities, that can be brought by the multilink solutions, the experimental studies were conducted in IRT testbed. The received results showed the high level of effectiveness of wireless channel bonding during the mobility. The received results gave the possibility to estimate channel utilization and to follow the dynamic redistribution of the channels capacities.

ACKNOWLEDGMENTS

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