MULTILINK APPROACH FOR THE CONTENT DELIVERY IN 5G NETWORKS

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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 defined use cases, it is necessary to provide needed throughput, delay and reliability. For this purpose, the multi-connectivity approach can be used. 5G multi-connectivity is one of the key enablers in order to satisfy the demanding requirements of 5G mobile networks. Multilink is one kind of multi-connectivity within the 5G-Xcast project. This paper describes multilink benefits, its high-level description and implementation to the 5G core architecture for better user experience and reducing costs of mobile network operators.**

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

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 objectives of the project are 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 (4k/8k Ultra-High-Definition Television (UHDTV), HDR (High-Dynamic Range), HFR (High Frame Rates) and wide color space, object based content etc.) delivery with the best quality of user experience. There were identified uses cases relevant for the project, including use cases relating to M&E, PWS, Automotive and IoT [1, 2]. For these use cases it is necessary to provide needed throughput, delay and reliability. The multi-connectivity approach can be used for this purpose.

II. Multi-connectivity approach

A. *Multiconnectivity*

Multi-connectivity (MC) of single user terminals to multiple radio access points is a 5G key enabler in order to satisfy the demanding requirements of 5G mobile networks [3]. Multi-connectivity supports simultaneous connectivity and aggregation across different technologies such as 5G, LTE, and unlicensed technologies such as IEEE 802.11 (Wi-Fi), may be Li-Fi in the future (Fig. 1).

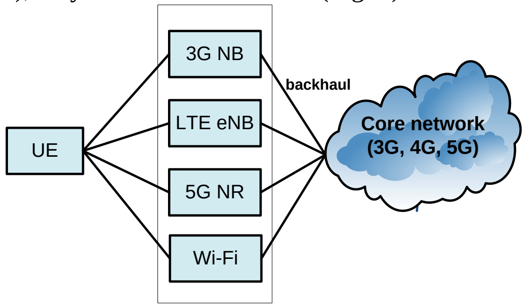

Fig. 1. 5G architecture with Multi-connectivity

In addition, it may connect to multiple network layers such as macro and small cells and multiple radio access technology (RAT) layers such as below 6GHz and mmWave [4].

Possible multi-connectivity protocol stacks are shown on the Fig. 2.

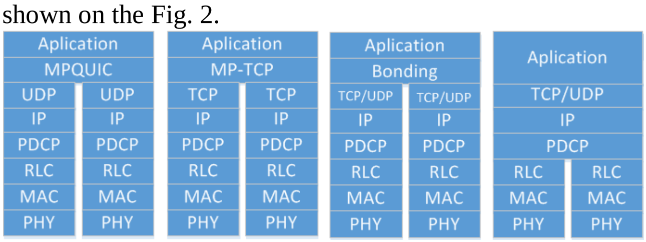

Fig. 2. Multi-connectivity protocol stacks

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

III. Backgrownd work

In previous papers were described some widespread and well-known MC 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].

Dual Connectivity (DC) is a capability of a device to connect to two base stations (of the same technology) simultaneously [5]. Multi-RAT Dual Connectivity (MR-

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DC) is a generalization of the Intra-E-UTRA Dual Connectivity (DC) described in 36.300 [2], where a multiple Rx/Tx UE may be configured to utilise radio resources provided by two distinct schedulers in two different nodes connected via non-ideal backhaul, one providing E-UTRA access and the other one providing NR access.

In some cases parallel usage of available Wi-Fi and cellular networks can also provide better user experience. The following mechanisms have been standardized within Rel-13 under the LTE-WiFi RAN-level integration framework [6]:

- LTE-WLAN Aggregation (LWA): is basically an evolution of Dual Connectivity, where the secondary link is provided by the WiFi Access Point (AP) [6].
- RAN-Controlled LTE-WLAN Interworking (RCLWI) [7]: is also based on WT and Xw interface upgrade of the WiFi network for control signaling, however, the User Plane (UP) bearers instead of going through the LTE eNB are routed through a CN with WiFi legacy link.
- LTE-WLAN Radio Level Integration with IPsec Tunnel (LWIP) [8]: provides the possibility to aggregate resources from WiFi and LTE simultaneously (similar to LWA), but without requiring the upgrade of the WiFi network (i.e. enabling the use of legacy WiFi networks).

But in this paper, we will focus only on one specific architecture options which allow for integrating multi-connectivity into 5G networks.

IV. PROBLEM STATEMENT

Within the project there were identified main use case for multiconnectivity. Mobile device (user equipment) is on the edge of the broadcast/multicast (BC/MC) area. Note, that "edge area" means edge in terms of service level (underground etc.) (Fig. 3).

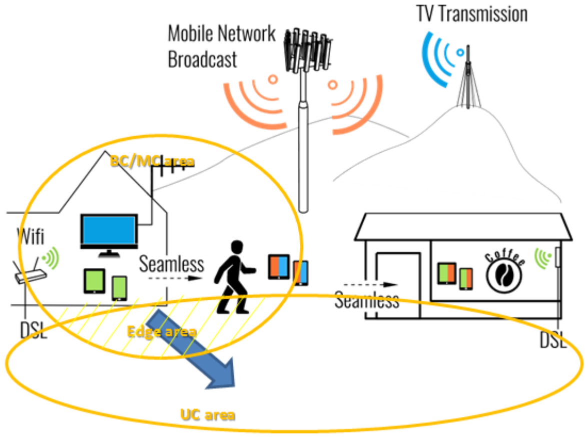

Fig. 3. Multilink implementation on the edge of the MC/BC and UC areas

In this case the next conditions and limitations are taking place:

- Poor BC service or a mobile user going in and out of that service area;
- The content is transmitted to that user also in unicast (UC);
- It is the same content (or a FEC or similar version of it).

So, a user can generate a full quality and reliable video if he receives only the unicast in good quality. It will allow the user to get the best quality video over UC as well as seamless and quick transition between MC and UC, including during mobility and in a house.

Multiconnectivity can potentially attract many users for:

- Huge file transfer;
- High/very high definition video streaming;
- Object based content delivery.

Switching from multicast to unicast for this use case can be extremely beneficial in terms of seamless transition between different areas.

Two actors will benefit from this scenario:

- End User: improved QoE;

Network Operator: lower network resource usage.

So, it was decided to improve 5G core architecture to provide novel MC solutions like multilink.

V. 5G –XCAST ARCHITECTURE WITH MULTILINK

A. *Multilink*

In this paper, we will use the term multilink (ML) to refer to all these different mentioned above technologies in general, since the key reference scenario will be 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. In these strategies, a MLF (multilink functionality) is able to reroute the data packets through the different available links, and a ML-MW (Multilink middleware) performs the adequate connection merger operation at the UE. The ML-MW at the viewing user side communicates with the MLF which can be located either at the core network, the publisher, or the cloud depending, for example, on deployment constrains. These two entities (ML-GW and MLF) exchange information about the performance of each link.

B. *Multilink usage strategies*

There are several options for implementing ML strategies, which are also related to the key objective of the ML usage. ML can be used for improving reliability, providing ancillary information, increasing available bandwidth (e.g. higher video resolution), or performing traffic optimization. Due to this diversity, the use of the multiple connections can be quite distinct in different models. The main methods for multi-connectivity can be described as:

1. "Replicate": Deliver the same content over all available connections.
2. "Switching": Send all the content on one link and then switch between links as a fail-over mechanism.
3. "Load balancing": Balance the content between all links so that each data flow, or IP destination, or application, use one of the links.
4. "Complementing": A specific load balancing approach, which uses the key stream information on the

primary link and provides additional information on the secondary link.

5. “Bonding” or “Aggregation”: Treat all available links as a single virtual broadband link and split all the content between all available links dynamically according to the performance of each of the links and the total available “goodput”.

It is noted that not all of these methods use multiple connections simultaneously. In particular, the benefits of bonding can be listed as follows:

1. *Overall bandwidth.* The possibility to deliver broadband content that would be impossible to deliver over a single link. For example, if a certain video stream needs 15 Mb/s and the single link is capable to deliver only 10 Mb/s, then this content could not pass over a single link. However, when bonding and aggregating at the application layer at least two such links, the total available bandwidth becomes 20 Mb/s which makes this delivery possible. This technology is advantageous to 5G-Xcast since video content (especially with current high video resolution trend) is usually either a live stream or a very large file to download, and individual links even 5G ones, are not always sufficient.

2. *Reliability and availability of the service.* In any single layer-2 link, especially in a wireless environment, the fluctuation in bandwidth, latency or error rate can be dramatic. Using multiple links as a virtual single broadband connection could mitigate these fluctuations. Seamless transition between single-L2-link and multilink using unicast and multicast/broadcast (and the other way around) could be achieved in a reliable way due to the use of simultaneous multiple networks in a dynamic way. Seamless transition is a feature clearly identified in MooD and Service Continuity specified in 3GPP TS 26.346[10], and it would be expectable for such feature to be retained in multilink usage.

3. *Mobility support.* The first two feature benefits also imply that the mobility (including at high speed) is supported in an improved manner. In this case, mobility means the seamless transition between coverage areas of different networks or technologies, with continuous QoS and QoE. For instance, the end user can enjoy a seamless viewing experience when moving from the office to the home using the same mobile device. In some cases (e.g. live video), it is possible to add an integrated video encoding process which outputs a live encoded or just-in-time transcoded video stream that adaptively matches the momentary performance of the multiplicity of virtually bonded links. However, this is not one of the primary scenarios in the 5G-Xcast project.

C. Multilink implementation to the 5G-Xcast architecture

There are three 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 5G-Xcast MLF is integrated with the relevant NFs in an exemplary one of the currently discussed three core architectures. The paper consider three different types of relevant ML component:

- ML-CP – additional functionality in Control Plane of the Core network, which performs QoS parameters estimation for data transfer via each available link, multilink session setup and release initiation;
- ML-UP – additional functionality in Data Plane of the Core network, which performs data splitting, IP tunnels establishment;
- ML-MW – ML middleware functionality in the UE, between the Application and the lower transport levels, which performs data combining, signaling (channel quality data transmitting), caching, providing ML session setup request (QoS parameters).

The architecture (for example, Alternative 1) with data flows describes the process of data transfer, using ML (Fig. 4).

Additional functionality, which must be included to the several NFs, is listed below:

XCF:

- Multilink session setup and release initiation
- QoS parameters estimation for data transfer via each available link

UPF:

- Data split
- Establishment of IP tunnels
- Establishment of IP tunnels

SMF:

- Multilink session setup and release

Converged middleware:

- Data combining
- ML session Setup Request (QoS parameters)
- Signaling (channel quality data transmitting)
- Caching.

An example of data transition with ML is described as follows. There is one common data stream from Content Server, which is transferred to UPF via N6 interface. UPF splits data flow between (R)AN and non-3GPP access. After receiving in Converged middleware split data is combined by ML-MW into one common stream. Note, that data split will be provided by UPF and data combining by ML-MW for each alternative. There will be a difference only in control plane functions.

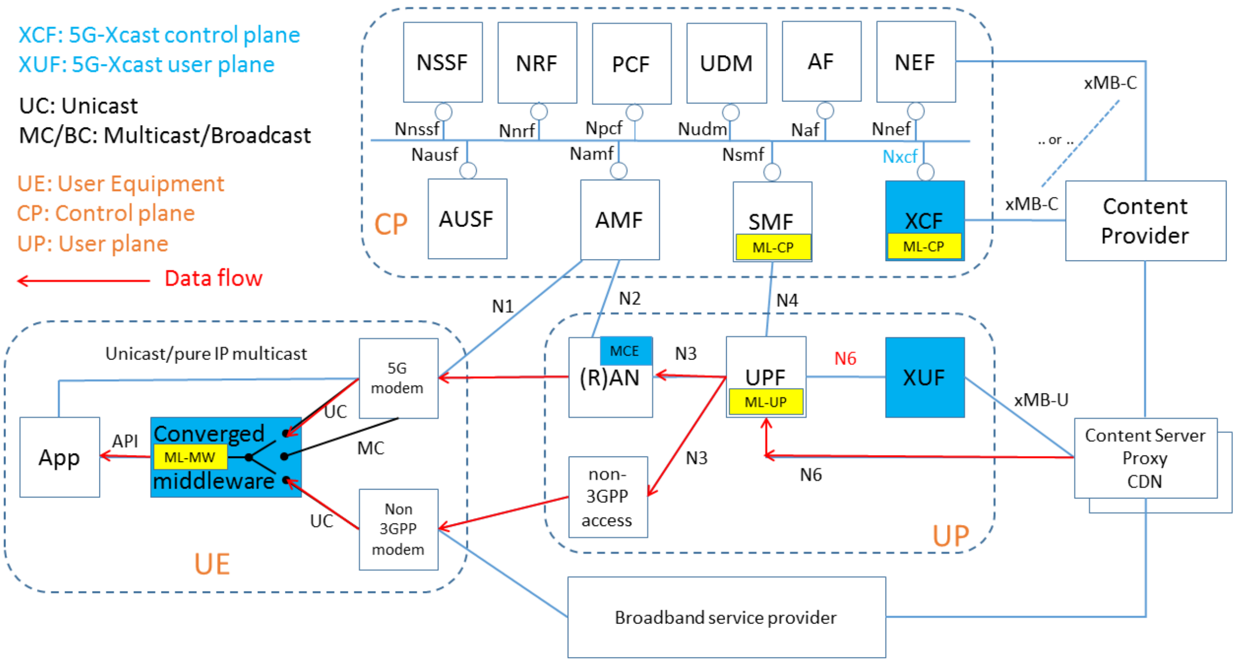

Fig. 4. Multilink data flows in 5G-Xcast architecture

VI. 5G – Mapping between 5G-Xcast core architecture with Multilink and ongoing 3GPP standards

The purpose of this section of the paper is to study how the 5G-Xcast core network with multilink is mapped with the on-going work in 3GPP on "System Architecture for the 5G System" (TS 23.501 [10]), "Procedures for the 5G System" (TS 23.502 [11]) and "Study on Access Traffic Steering, Switch and Splitting support in the 5G system architecture" (TR 23.793 [12]).

The status of WiFi (non 3GPP in general) Access integration into the 5G Core ongoing work, represented in TS 23.501 is the following [10]:

- Connectivity of the UE only via non-3GPP access networks (e.g. WLAN access) is allowed.

- Non-3GPP access is standalone untrusted non-3GGP access.

- Non-3GPP access networks are connected to 5G core network via a Non-3GPP InterWorking Function (N3IWF):

a) A UE shall establish an IPSec tunnel with the N3IWF, the UE shall be authenticated by and attached to the 5G Core Network during the IPSec tunnel establishment procedure.

b) N1 NAS signaling over standalone non-3GPP accesses shall be protected with the same security mechanism applied for N1 over 3GPP access.

- A UE access the 5G Core Network supports NAS signaling using N1 reference point

- The N3IWF interfaces to 5G core network control-plane functions and user-plane functions via N2 interface and N3 interface, respectively.

- Only Untrusted Non 3GPP Access is currently in scope, Trusted being discussed for R16

All solutions considered in the document TR 23.793 are based on and aligned with the 5GS Phase-1 normative work including work on policy management, as in mentioned above documents in TS 23.501, TS 23.502 and TS 23.503.

In particular, the document TR 23.793 considers solutions which specify the following:

- How the 5GC and the 5G UE can support multi-access traffic steering between 3GPP and non-3GPP accesses.

- How the 5G Core network and the 5G UE can support multi-access traffic switching between 3GPP and non-3GPP accesses.

- How the 5G Core network and the 5G UE can support multi-access traffic splitting.

The scope of this document excludes the following aspects:

- Changes to the charging framework are not considered. However, it may be considered what information needs to be provided to the charging framework in order to charge traffic that is switched and/or split between 3GPP and non-3GPP accesses.

- ATSSS procedures, which may be applied in the NG-RAN, are not considered. The study is restricted only to ATSSS procedures applied in the 5G core network.

- 5GS enhancements to support trusted non-3GPP access networks are not considered.

- 5GS enhancements to support wireline access networks are not considered.

The study in this document [11] is organized into two phases. Currently, the study considers ATSSS solutions that enable traffic selection, switching and splitting between NG-RAN and untrusted non-3GPP access networks. And only after the 5GS architecture is enhanced to support trusted non-3GPP access networks, the study will also consider ATSSS solutions that enable traffic selection, switching and splitting between NG-RAN and trusted non-3GPP access networks.

Comparing existing solutions within 3GPP documents mentioned above [10-12], Multilink gives more freedom and possibilities to integrate 3GPP and non-3GPP (trusted and non-trusted) accesses into the 5G architecture (e.g. Wi-Fi, wireline, satellite etc.). As was mentioned above, there are several strategies of using multiple links within 5G-Xcast project, depending of external circumstances: replication of the content, switching between links, load balancing, complementing via additional links and bonding and aggregation. For each exact use case it will bring more benefits than not yet fully defined 3GPP solutions.

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. So, this paper described how the 5G-Xcast ML functionality is currently integrated with the relevant NFs in an each of the three 5G-Xcast core networks architecture alternatives. The functionality, which is needed for ML operations in UPF, XCF, SMF and novel proposed ML-MW, was described as well.

In the last section it was analyzed how the 5G-Xcast core network with Multilink is mapped with the on-going work in 3GPP. Comparing to the solutions provided in the 3GPP, ML gives more freedom and possibilities to integrate 3GPP and non-3GPP (trusted and non-trusted) accesses into the 5G

REFERENCES

[1] 5G-Xcast – The official website for the 5G-Xcast project http://5g-xcast.eu/

[2] Ten key rules of 5G deployment, 2015.

[3] F. B. Tesema, A. Awada, I. Viering, M. Simsek, and G. P. Fettweis, “Mobility modeling and performance evaluation of multi-connectivity in 5G intra-frequency networks,” in 2015 IEEE Globecom Workshops (GC Wkshps), Dec 2015.

[4] H. Shokri-Ghadikolaei, C. Fischione, G. Fodor, P. Popovski, and M. Zorzi, “Millimeter wave cellular networks: A MAC layer perspective” IEEE Transactions on Communications, vol. 63, no. 10, pp. 3437– 3458, Oct 2015.

[5] Claudio Rosa and others “Dual connectivity for LTE small cell evolution: Functionality and performance aspects” IEEE Communications Magazine 54(6):137-143

[6] "Revised WID: LTE-WLAN Radio Level Integration and Interworking Enhancement", *Intel 3GPP RAN Plenary #70 Sitges Spain*, Dec. 2015.

[7] "New Work Item on Enhanced LWA", Intel Qualcomm China Telecom 3GPP RAN Plenary #71 Göteborg. Sweden, Mar. 2016.

[8] "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE-WLAN Aggregation Adaptation Protocol (LWAAP) Specification", [online] Available: www.3gpp.org.

[9] TS 36.300 “Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2”

[10] TS 23.501 “System Architecture for the 5G System”

[11] TS 23.502 “Procedures for the 5G System”

[12] TR 23.793 “Study on Access Traffic Steering, Switch and Splitting support in the 5G system architecture”