5G-Crosshaul: The 5G Integrated Fronthaul/Backhaul

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***Abstract*— This work presents 5G-Crosshaul: the 5G Integrated Fronthaul/Backhaul. 5G-Crosshaul aims at developing an adaptive, sharable, cost-efficient 5G transport network solution integrating the fronthaul and backhaul segments of the network. This transport network will flexibly interconnect distributed 5G radio access and core network functions, hosted on in-network cloud nodes, through the implementation of two novel building blocks: *i)* a control infrastructure using a unified, abstract network model for control plane integration (Crosshaul Control Infrastructure, XCI); *ii)* a unified data plane encompassing innovative high-capacity transmission technologies and novel deterministic-latency switch architectures (Crosshaul Packet Forwarding Element, XFE). 5G-Crosshaul will greatly simplify network operations despite growing technological diversity. It will hence enable system-wide optimisation of Quality of Service (QoS) and energy usage as well as network-aware application development.**

***Index Terms*— C-RAN; fronthaul; LTE PHY; CPRI; 5G.**

I. Introduction

The fifth generation (5G) of network technologies will be characterised by the extremely wide bandwidth that will be available to the user. In order to provide such a huge increase in available bandwidth, 5G radio access network (RAN) technologies serving this mobile data tsunami will require fronthaul and backhaul solutions between the RAN and the packet core capable of dealing with this increased traffic load. Further, there will be a sizable growth in the capillarity of the network since data rate increase in the 5G RAN is expected to stem to a large extent from increasing the number of base stations and reducing their coverage, i.e., mobile network densification.

Current fronthaul/backhaul links are already known for their stringent delay and jitter requirements. These requirements will be even extended if applied to 5G which will use wider channels (e.g., 100MHz channels are currently being discussed), requiring of novel techniques to carry all this information in the fronthaul/backhaul links.

Given that the aforementioned challenges will need to be addressed by service providers in a business environment where a revenue increase proportional to the data volume increase is unrealistic, a cost-efficient network deployment, operation and evolution strategy is required.

In this paper we present the 5G-Crosshaul architecture. 5G-Crosshaul will built on top of current C-RAN technologies, considering novel ways of decomposing the base stations [1] (the so-called flexible functional split), where the split between centralized and distributed base station functions can be adjusted on a case-by-case basis. The 5G-Crosshaul will act as a bus/transport network connecting Radio Heads (RH) to Base Band Units (BBUs) which will be virtualized and hosted in Data Centres. Once virtualized, base station functions can be flexibly distributed and moved across data centres, providing another degree of freedom for load balancing.

The 5G-Crosshaul aims at integrating the currently differentiated fronthaul and backhaul networks. This new generation of 5G-Crosshaul technologies will be needed to bring the CAPEX and OPEX investments to a reasonable return on investment (ROI) range. Also for cost reasons, the heterogeneity of transport network equipment must be tackled by unifying data, control and management plane across all technologies as much as possible.

II. 5G-Crosshaul Architecture

To address the aforementioned challenges, we propose the 5G-Crosshaul architecture which aims at developing the next generation of 5G integrated backhaul and fronthaul networks enabling a flexible and software-defined reconfiguration of all networking elements in a multi-tenant and service-oriented unified management environment. The 5G-Crosshaul transport network envisioned will consist of high-capacity switches and heterogeneous transmission links (e.g., fibre or wireless optics, high-capacity copper, mmWave) interconnecting Remote Radio Heads, 5G Points of Attachment (e.g., macro and Small Cells), pooled-processing units (mini data centres), and points-of-presence of the core networks of one or multiple service providers.

To this end, evolutions and completely novel physical layer technologies must be designed, such that the challenging 5G performance requirements can be met. The 5G-Crosshaul architecture will use a novel unified data plane protocol able of transporting both backhaul and fronthaul traffic, regardless of the functional RAN split.

Furthermore, the designed unified data-plane protocol must allow for future RAN evolution, which may happen on shorter timescales than transport network upgrades. The new data plane will also need the adaptation of switch architectures to support the required latency and jitter demands. Hence, significant effort is needed towards the development of the

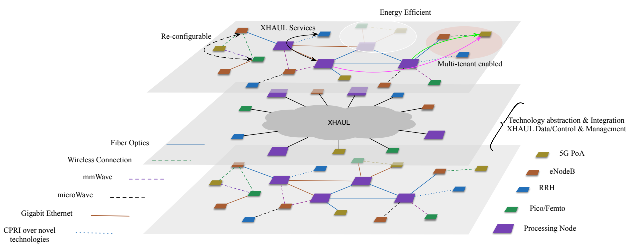

Fig. 1. 5G-Crosshaul Functional Structure

combination of transmission technologies, switch architectures and protocols in a way that allows transporting CPRI/OBSAI ([2], [3]) data in a packetized form over the unified 5G-Crosshaul data plane.

Finally, the novel architecture will also require the development of a unified control and management plane (network model and interface primitives) to simplify network operations across heterogeneous technologies. It is understood that the 5G-Crosshaul architecture must be able to coexist with legacy infrastructure and must allow operators a smooth migration. The key idea of the proposed architecture is to move from a traditional transport network perspective to a novel architecture integrating both fronthaul and backhaul into the 5G-Crosshaul transport network.

Fig. 1 shows the 5G-Crosshaul functional structure and the new 5G-Crosshaul services. The lowest layer corresponds to the overlay of all infrastructure layers, showing the networking infrastructure, formed by heterogeneous links connecting the different elements of the planes located above. The middle layer represents one of the key concepts associated to 5G-Crosshaul: the integration of the different technologies (including fronthaul and backhaul) in a common packet network based on technology abstraction, unified framing and common data, control and management planes. The Interconnection Plane makes use of Crosshaul Packet Forwarding Elements (XFE) to interconnect a broad set of novel technologies to create a packet-based network that can meet the demands of 5G networks.

Finally, the upper layer presents a selection of the features envisioned for the 5G-Crosshaul infrastructure. These services are provided by the 5G-Crosshaul Processing Units (XPUs) that carry out the bulk of the operations in the 5G-Crosshaul. The functionality provided by these XPUs is multi-faceted. It highly depends on the actual interconnection and must encompass functionality expected from the different elements in the 5G network. The following services will be provided on top of the architecture described above:

- *Re-configurability* to cope with the level of demand expected from 5GPoAs, the 5G-Crosshaul must be able to allocate capacity in a dynamic way, reallocating resources from areas where they are not needed to meet the demands in busier areas (e.g., joint RAN and 5G-Crosshaul capacity optimization).
- *Energy efficiency* through techniques to reduce the energy consumption of the different 5G-Crosshaul elements, combined with the joint optimization of RAN and 5G-Crosshaul resources in terms of dynamic de-activation or decommissioning of scarcely used network portions.
- *Multi-tenant operation* to enable a generalized sharing and more efficient utilization of the underlying resources, 5G-Crosshaul will implement the concept of multi-tenancy at the infrastructure level. Moreover, 5G-Crosshaul allows operators and Over-the-Top (OTT) companies to quickly deploy services within the 5G-Crosshaul platform as Video On Demand, HD videoconferencing, TV broadcasting, CDNs and cloud services.

The control and management plane of the network will be handled by a set of controllers (XCIs) interacting with the data plane through a novel Southbound Interface capable of supporting the multiple technologies available in 5G-Crosshaul physical layer. The XCI not only controls packet forwarding (i.e., the XFE behaviour) but also the physical layer parameters (including optical equipment). The XCI will implement a powerful and open Northbound Interface (NBI) to support a variety of network applications running dedicated optimization algorithms and functions for specific 5G-Crosshaul features, such as capacity reconfiguration, forwarding and Infrastructure on Demand (IoD) features.

III. Summary and Conclusions

Next generation radio access networks will be characterised by a higher degree of capillarity, density and higher bit rates. This will push to the limit the network segments connecting the RAN to the Core of the network, the so called backhaul. At the same time, new models for the design of base stations separating radio and base band processing in different nodes separated geographically and connected by specific purpose communication lines (fronthaul) are being deployed by operators as a way of decreasing the OPEX/CAPEX of their networks. With the increase in bandwidth required for 5G, non-integrated fronthaul/backhaul architectures are not expected to be able to cope with the new capacity requirements in a cost-effective manner. Therefore, industry is currently looking to architectures enabling to take the C-RAN concept to the 5G era. This paper has presented the 5G-Crosshaul architecture, a novel proposal aiming at integrating fronthaul and backhaul in a single transport network connecting radio heads and virtualized base band units, while providing overal resource optimization and reducing the service creation time and the CAPEX and OPEX.

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