Evolution of Access Network Sharing

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Network sharing is part of a fundamental principle of statistical multiplexing of link capacity. Regardless of whether the nodes are setting up connections that reserve capacity in the Plain Old Telephone Service (POTS), or sending packets in a connection-less packet-switched network, the overall link capacity is only a fraction of the total interconnection capacity required if all nodes attempted communicating at once. Network sharing also applies to the progressive aggregation of link capacity where the ratio of multiplexing increases in moving from the access towards the core. From the mid-90s', the concept of sharing was extended to also cover the multi-tenant use of the network, where third party network operators compete with the incumbent national operator, so that the same common infrastructure is shared across multiple competing entities. The degree to which infrastructure is shared is limited, on the one hand by physical and logical boundaries that separate resources, and on the other hand by economic complexities such as settlements, agreements and regulations that complicate the sharing process.

Keywords: Optical Network Sharing, 5G Infrastructure

1. Introduction

By its nature, a telecommunications network is a shared resource that interconnects multiple nodes. Network sharing is part of a fundamental principle of statistical multiplexing of link capacity. Regardless of whether the nodes are setting up connections that reserve capacity in the Plain Old Telephone Service (POTS), or sending packets in a connection-less packet-switched network, the overall link capacity is only a fraction of the total interconnection capacity required if all nodes attempted communicating at once. Network sharing also applies to the progressive aggregation of link capacity where the ratio of multiplexing increases in moving from the access towards the core. From the mid-90s', the concept of sharing was extended to also cover the multi-tenant use of the network, where third party network operators compete with the incumbent national operator, so that the same common infrastructure is shared across multiple competing entities. The degree to which infrastructure is shared is limited, on the one hand by physical and logical boundaries that separate resources, and on the other hand by economic complexities such as settlements, agreements and regulations that complicate the sharing process.

Recently, technology evolutions based on Software Defined Network (SDN) and Network Function Virtualization (NFV) have enabled network multi-tenancy that increases the flexibility and level of network control automation and management processes, in ways that were not possible before. These characteristics arise because of virtualization, which enables different entities to get access to a subset of the network resources, while giving the illusion of fully owning that part of the infrastructure. This separates the operations of one tenant fully from other tenants that share the same physical infrastructure.

5G networks are designed to provide higher capacity and to improve performance metrics such as latency, packet loss and availability. The corresponding increase in infrastructure cost requires the network to be shared efficiently across many services and tenant operators. Densification of access points and the virtualization of the access network has thus become a fundamental principle in the design of 5G networks. In addition, the growth in infrastructure investment for the 5G networks is challenging the conventional standalone network ownership model. Operators [1] can save between 20 and 55% in CapEx by sharing their assets, depending upon how much infrastructure is shared. The 5G Infrastructure Public-Private Partnership (5G PPP) [2] believes that new resource sharing business models are the key enablers for the success of 5G.

2. Access Sharing Models

Sharing of access networks can be achieved through a number of different architectures and models. Typically there is a trade-off between the ability of Other Licensed Operators (OLOs) to control the level of service offered to their users and the complexity and amount of infrastructure that each OLO needs to deploy. For example, physical layer unbundling provides OLOs with the highest level of control, as they can tap directly into the end-user's physical transmission link, that is, in the case of copper-based Digital Subscriber Line (DSL) access. However, it requires the OLOs to have their own physical infrastructure deployed in (or near) each local Central Office (CO) where they intend to serve the customers.

On the other hand, higher layer unbundling, like bitstream access, discussed in more details later, allows OLOs to collect their customer traffic at a small number of points of presence (POPs), thus reducing the amount of equipment deployed in the network. However, these models provide OLOs with very limited control over the type of services they can deliver to the users, as typically they can only offer a small number of broadband packages to their customers. The next sections delve into the details of the most popular access network sharing paradigms.

3. Sharing of Optical Access Networks

Because fiber optic technology has large bandwidth capacity and low signal attenuation, it has largely superseded copper transmission in telecommunications networks. The only exception is in the network access, where short sections of copper lines are still used. Copper wire is used, in conjunction with fiber distribution, to deliver higher bandwidth DSL such as VDSL and G.FAST. Despite the cost of delivering new fiber to residential premises, an increasing number of operators are investing in FTTH deployment, in order to provide a future-proof mechanism to deliver higher capacity to residential and business clients. Indeed, optical access networks, in their different forms, are today the technology of choice for operators upgrading their network, offering high-speed broadband to both residential and enterprise users. Because optical access networks were deployed after the de-regulation of telecoms networks, line unbundling regulations do not necessarily apply, and different regions have adopted completely different approaches. The US, Europe and Japan are an example where different regulatory choices have led to different levels of FTTH deployment, with Europe and the US having experienced a much lower coverage than Japan [3].

Thus, sharing of optical access networks is today not common across the world. In places where sharing is in place, the approach has typically been limited either to fiber unbundling, that is, where the optical access is point-to-point fiber, or to higher layer NGA bitstream. In NG-PON2, where multiple wavelengths are available, it is possible, in principle, to separate OLOs by wavelength. However, there are still a number of technical issues. One issue relates to the ownership of the Optical Line Terminations (OLTs), as multiple wavelengths could interfere in certain cases, if not controlled by the same system. Another issue is that the allocation of a PON wavelength to one OLO is static and inefficient, preventing capacity unused by one PON to be used by other operators. Furthermore, NG-PON2 currently defines only 8 wavelengths for Time Division Multiplexing (TDM) access and the technology is not yet widespread, due to the high cost of the end-users tunable Optical Network Terminals (ONTs). More dynamic techniques have been discussed, for example in [4][5], and could be made technically feasible with the recent development of SDN and NFV in the central office [6]. In the rest of this section, we briefly introduce some of the prevailing optical access technologies and review their major challenges with respect to multi-tenancy.

4. Software Defined Network (SDN)

Initially devised as a mechanism to separate control and data plane in network switches and routers, SDN has in only a few years evolved into a comprehensive framework to add flexibility and programmability to the entire telecommunications network. These features have led to SDN being considered as an essential element to deliver network multi-tenancy.

5. Fixed Access Network Sharing Economics

We have already explored the principles of fixed access network sharing and the technologies that enable it. We have seen that, for example, multi-wavelength systems, such as NG-PON2 can provide both high capacity, isolation and flexibility of operation in shared networks. However, one of its main disadvantages is that it requires ONTs to be equipped with tunable lasers and filters, making them expensive. Indeed, the body of European Regulators for Electronic Communications (BEREC) has published a Report [7] on the New Forms of Sharing Passive Optical Networks Based on Wavelength Division Multiplexing. In a BEREC questionnaire completed by 50 European network operators, more than 20 per cent of the operators have mentioned that the expense of the NG-PON2 equipment was one of the main reasons why it is not likely that the network operators will deploy NG-PON2. On the other hand, only four operators have considered wholesale wavelength unbundled services and the reuse of the passive network infrastructure as primary reasons for the network operators to deploy NG-PON2 [7]. We have seen Section 3 that Time Division Multiplexing is an enabler for network sharing. However, network operators are unlikely to invest in fine-grained sharing models without some economic incentives.

6. Conclution

We briefly introduced the state-of-the-art solutions to some of these challenges, including a market model to provide trading incentives through monetization of the excess resources and then modelling the multi-tenant PON as a bilateral trade market. Multi-tenancy could potentially facilitate new partnership and co-investment models for network operators. In this report, we addressed one such model in which a trusted infrastructure provider is the sole provider of the resources. However, more complex sharing models are yet to be addressed as new network ownership/operation models emerge thanks to the network virtualization.

Finally, we conclude this paper with a few insightful remarks on possible future research:

- Designing and regulating new access network ownership models should be a key policy priority to ensure smooth deployment of 5G networks.
- More research is needed to determine the business implications of the new ownership models, presumably utilizing novel approaches such as blockchain and smart contracts to assure economic robustness and trust.
- Further studies should assess the potential for other network component/function virtualization opportunities to enhance the flexibility of the shared access.

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