Wireless Open Access Networks: State-of-the-art and Technological Opportunities

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Abstract—The present article provides a literature review in the field of open access networks and points out additional strengths of infrastructure sharing in the advent a new wave wireless advances. The first part of the article summarizes different initiatives carried out both by researchers and practitioners around the globe. The focus is on finding commonalities in what have been, until now, disperse efforts. A perspective on the current regulation regarding open access networks in the framework of the European Commission is also provided.

The second part of the article reviews some recent proposals to increase the performance of wireless networks. It is explained that the idea of deploying a shared wireless infrastructure (as opposed to multiple ones), presents some additional advantages when combined with opportunistic scheduling in OFDMA and the use of wider channels for increased throughput. The concept of collaborative networks is gaining momentum and it is also closely related to the idea of infrastructure sharing.

Keywords—Wireless open access networks; wireless technological trends.

I. INTRODUCTION

Open and neutral access networks has been a rather unexplored research field until now. Openness is related to the possibility of interconnecting and expanding the network while the neutrality guarantees equal terms to all of those that are willing to offer services on top of the network.

Although openness and neutrality seem to be desirable properties of an access network, as of today, they are mostly the exception and not the rule. Some groups of researchers and practitioners have explored the idea of designing and deploying open and neutral access networks, particularly in those environments in which the traditional models do not fit.

Some examples are grassroots community networks, network infrastructure in underdeveloped countries payed by donors, and network infrastructure deployed by municipalities as a service to the citizens. In those kinds of networks, openness and neutrality are encouraged and implemented.

Most of the research and implementation initiatives have been carried out independently, with a lack of communication and awareness about similar projects. The terms open and neutral may have different interpretations in different environments, and the drivers beyond the initiatives were also completely unrelated. Until now, there was not a common forum to share experiences and know how, and to join forces for future projects.

The main goal of the present article is to summarize the ideas coming from different works that are related with open access networks. Although heterogeneous, it is possible to find commonalities in the described initiatives.

As opposed to the research in open access networks, that has been sparse and disperse, the research on next generation wireless system has received many efforts and there is a common agreement in which are going to be some of the trends that will enhance the performance of upcoming networks. These trends include the use of wider channels, orthogonal frequency multiple access and collaborative communications. In this article we will explain why these new trends are particularly well aligned with the open and neutral access concepts.

The remainder of the paper is organized as follows. Section II summarizes previous work in the field of neutral open access networks. Then, Section III reviews some of the latest trends in wireless communications and why they are particularly suited for neutral open wireless access networks. Finally, Section IV concludes the paper.

II. PREVIOUS WORK AND RELATED INITIATIVES

This section presents a comprehensive literature review of neutral open access networks. Previous work is characterized by its heterogeneity, including theoretical contributions, testbeds, grassroots initiatives and regulatory framework.

A. The Neutral Open Access Network Concept

The term open access network, in the context of wireless networks, was coined in [1], in which it was proposed that the last mile was covered by shared infrastructure. This sharing translates in cost reduction that benefits both the users and the operators. The article also presents a formal definition of the terms open network and neutral network as a set of rules that the network must satisfy. We reproduce that set of rules here for the sake of completeness:

An open access network must satisfy:

- Any user must be free to select any service provider on the network;
- Any service provider must be free to deliver services over the network to any user;
- Anyone should be allowed to add access points to the network and anyone should be allowed to extend the shared part of the network.
In a neutral access network:

- Service providers should be offered transport (or bearer) services at different architectural levels and refinements, so that different services and different providers can find their natural place in the network;
- All service providers must be offered the same conditions;
- There can be no disloyal competition, and the owner (or operator) of the neutral access network is not allowed to offer services to end users.

The breakthrough comes from substituting the current vertical paradigm, in which a single actor provides both the infrastructure and the services, for a horizontally layered one. In the horizontal layer approach (See Fig. 1), an entity is responsible for the infrastructure deployment and operation and offers its services to the entities that provide services using a well-defined interface. The similarities with the ISO/OSI layered model are remarkable.

Since the access network is the bottleneck of today’s Internet, the idea of using inexpensive wireless hardware to create a communication service that is an alternative to the incumbent fixed and mobile infrastructures is tempting. The open and neutral model can also be applied to fiber [2], as occurred in Sweden with Stokab and in Utah with UTOPIA [3].

The neutral open access network approach is also presented as a valid alternative to contribute to the development of the ICTs in a given region without undermining local entrepreneurship. The argumentation is that basic infrastructure (such as dark fiber) can be offered to all local business under the same conditions. This will foster competition at the same time that the risk and CapEx (i.e., upfront costs) is reduced for the local entrepreneurs. [4]

Note that the concept of Open Access Network is not tied to a given technology or business model. On the contrary, it is flexible enough to adapt and take different forms in different scenarios.

B. The University as a Catalyzer

The idea of wireless neutral open access networks has its origins in the university environment and the first testbed is presented in [5]. This implementation of the neutral open access network concept was deployed at the Kista-IT university. A later university-centric testbed in Barcelona is described in [6]. A university and its associated institutes might be willing to share their network resources in an open fashion. There is already a solid relation of trust and the incentive of providing a common framework to access the network for the personnel of the different institutions is clear. An neutral open access network has been successfully running in the university environment for several years.

An attempt was made to replicate the same approach in the streets (See Fig. 2) and public buildings of Barcelona. The municipality, the university and local ISPs joined forces to deploy a metropolitan-wide neutral open access network. Although the collaboration among competing ISPs proved particularly challenging, the metropolitan neutral open access network was operated as a testbed for several months and hundreds of users registered and tried the service.

A similar initiative is the deployment of a neutral access network based in the city of Urbino [7]. The university has a strong presence in the city, thus making it possible to provide a satisfactory coverage using the university network and premises. The challenge is to expand the network to neighbouring cities and to engage private operators to join the network while agreeing with the neutral open access philosophy. There have been advances in both fronts that make this case a promising proof-of-concept that could be used as a reference for other deployments.

In Trento, the university has also leaded efforts to implement the neutral open access network concept [8].

C. Grassroots community networks

One of the advantages of open access networks is to cover areas that traditional network operators do not deem profitable.
Under this conditions appeared guifi.net [9], [10], to link isolated houses in the Catalonian countryside using commodity hardware. This is a community-driven self-defined free (libre) open and neutral network that has presented a sustained growth to reach a number of active points over 6,000. The total distance covered by the radiolinks of this community network exceeds 7,500 Km.

The idea is that anyone can join the network by including one or more radiolinks. The participants retain the ownership of their hardware and gain the right to use the network. In addition to the connection to the Internet, guifi.net also has services provided by the community such as blogging, file repositories, web, network management tools and voice.

The success of the model has favored a growth beyond its original and natural environment to reach villages and cities. Today guifi.net is recognized as a European Living Lab and has received prizes and recognition from the local government.

There is also a citizen-driven urban open access network in Germany. It is called Freifunk [11] and it is described in [12].

The infrastructure deployed by these grassroots initiatives is not used by commercial service providers and thus the definition of neutral access network does not apply. They are simply open access networks.

**D. Open Access Networks as a Platform for Services**

The network exists to support services, and in today’s Internet it is clear that the services are provided by parties different than the infrastructure owners. Note that this is not the case in mobile network operators, in which the same entity provides both the infrastructure and most of the services.

Thus, by connecting the neutral open access network to the Internet, the users can automatically reach a plethora of services. Nevertheless, the locality of the access network can be exploited to deliver better or additional services. As an example, better voice services could also be offered as described in [13]. An additional service might be the provision of location information and the use of this information in emergency calls [14].

Local administrations could be engaged in contributing to the neutral open access network if they can envisage some new services that are perceived as added value, such as the possibility of easing e-governance or applications such automatic meter reading.

**E. Enabling Technologies**

The neutral open access network concept can be implemented in multiple ways. Although there are no products specifically designed for this purpose, there are a number of enabling technologies that can be used to share infrastructure. Wireless neutral open access networks are considered in [15] and five of these technologies are compared in terms of security, scalability, matureness and convenience. The technologies that are considered are dhcrelay, tunneling, multiple SSID, CAPWAP and IMS.

The conclusion is that, as of today, the most simple and direct way to share a wireless infrastructure is by announcing different SSIDs at the access points and redirecting each of them to a different VLAN.

An alternate enabling technology has been successfully used in [7], in which customized routing is used to redirect traffic to the corresponding ISP.

**F. A socio-economic perspective**

The debate around neutral open access networks expands beyond the purely technical to reach social, economic and political issues. The analysis is easily perturbed by heated discussions, such as the ones that surrounded municipal wireless. Although difficult, this analysis is particularly relevant and can easily determine the success or failure of the neutral open access approach. In [16]–[18] the final implications of the neutral open access networks for the different participating agents are discussed.

**G. Regulatory framework**

Network openness and neutrality is not only allowed, but recommended and, in many cases, enforced by regulatory authorities [19]. In the case of fixed access infrastructures deployed by incumbent operators (local loops, passive infrastructure), the European Commission regulatory framework enforces infrastructure sharing via local loop unbundling (LLU) [20], as well as ducts rental and co-ubication.

Regarding wireless networks, while no regulatory obligation exists to share networks infrastructure, European Commission and National Regulatory Authorities (NRAs) recommend passive infrastructure sharing among operators.

Municipalities and regional administrations are usually promoters of neutral network infrastructures in their territories in order to foster competition or to cover areas in which there is no incentive for traditional operators to deploy broadband networks (e.g., rural areas with disperse population). The regulatory framework prevents public administration to subsidize network infrastructures in areas that are already served by private companies. Nevertheless, public administration can deploy networks as long as they are self-sustainable and rely on expected return of investment, in the same way as private actors. A detailed study is presented in [21].

In those cases in which the lack of competitive broadband services instigates local and regional initiatives to invest taxpayer money in infrastructure, it is highly recommended that the infrastructure is shared in an open and neutral fashion. The infrastructure should be offered to service providers at cost-oriented prices. In [22] it is stated that deployment of open access infrastructure, defined according to technological neutrality and managed by an independent entity, appears to be the solution most conducive to effective competition. The goal is not to make profit from the infrastructure, but to encourage different service providers to operate (and compete) in the area.

As a conclusion, existing regulation enforces neutral models for incumbent essential facilities, such as passive infrastructures and local loops, fixing conditions for sharing these kind of infrastructure. It also allows (although do not enforces)
sharing models for wireless networks. Only in the case of public-funded wireless infrastructures, openness and neutrality are enforced.

III. WIRELESS TRENDS AND THEIR RELATIONSHIP WITH OPEN ACCESS NETWORKS

In the eternal quest for higher performance, the wireless research community is constantly proposing new advances. This section revises some of such advances that are, in our opinion, particularly well aligned with the idea of neutral open access networks. We refrain from repeating the advantages of neutral open access networks that have already been identified in the literature, such as the case of statistical multiplexing that is already pointed out in [1]. On the contrary, we focus on relatively recent trends, such as the increase of the channel bandwidth in the latest standard amendment IEEE 802.11n, the use of orthogonal frequency multiple access (OFDMA) and the use of cooperative communications.

A. Wider Channels

One of the features that introduces IEEE 802.11n [23] to enhance the throughput when compared to its predecessors is the doubling of the bandwidth of the channels from 20 to 40 MHz. This has become a core feature because of its low cost and simplicity. Almost all the 802.11n products on the market support a 40 MHz mode of operation [24].

However, an immediate consequence is the reduction of the number of available channels. Previous work [6] has already acknowledged the difficulties associated with the deployment of multiple overlapping WLANs belonging to different service providers due to the scarcity of non-overlapping channels in IEEE 802.11b/g [25]. This problem is even more acute with the new amendment to the standard, due to the doubling of the channel bandwidth. The solution is to use a common shared neutral open access network.

In principle, there is a drawback associated with packing too many stations in a single frequency channel. The coexistence of more contenders increases the chances of collisions in IEEE 802.11 networks. Nevertheless, this problem can be easily alleviated by using the approach presented in [26]–[28].

B. Orthogonal Frequency Division Multiple Access

Orthogonal frequency division multiplexing is multi-carrier modulation technique that has been widely adopted in recent wireless communications. It uses several closely-spaced subcarriers and each one transmits a low-speed data stream. It is robust in challenging channel conditions since it is unlikely that a large group of subcarriers is simultaneously affected by fading.

Given a set of subcarriers and a set of users, it is possible to intelligently assign carriers to users using orthogonal frequency division multiple access (OFDMA) [29]. This is particularly true in indoor nomadic scenarios where it is possible to acquire a good knowledge of the channel conditions.

In a neutral open access network, it is possible to take a holistic approach having a single radio resource manager to handle all the subcarriers and users. This would necessarily lead to an equal or better solution than in the case in which users and subcarriers are scattered among many different operators, each one running its own radio resource manager.

If multiple operators have to share a single band, it is better to assign interleaved subcarriers to each operator. Neighbouring subcarriers often present similar patterns, which hinder the benefits of OFDMA.

C. Cooperative and Relay Networks

Cooperative wireless access networks is a burgeoning field of research. As opposed to the approach in which each terminal autonomously transmits to the access point or base station, cooperative communications assume that multiple terminals or relays collaborate to improve the overall effectiveness of the network.

Cooperative access networks, when combined with appropriate coding techniques [30], can be used to improve the robustness of communications thanks to the increased diversity [31], [32].

The cooperation can take different forms. It can bee among peers, such as in [33], [34], or using fixed dedicated relays [35], [36]. In both cases, it is necessary that the two devices willing to cooperate are in each other’s transmission range. If the nodes, relays and base stations belong to several different access networks (operated by different providers), the opportunities for collaboration are greatly diminished.

A graphical explanation is presented in Fig. 3. Three operators (namely, the white, the grey and the black operator) deploy three different access networks. The white mobile terminal is far from both its base station and its relay, making the communication challenging. The same occurs with the other mobile terminals and their respective infrastructure. If the infrastructure was shared, the chances of being close to a collaborating relay or mobile terminal would be much higher.

![Fig. 3. Three access networks from different operators coexist. The multiplicity of access networks is an obstacle for collaboration.](image-url)
IV. CONCLUSION

This paper presents a comprehensive review of work on neutral open access networks, detailing theoretical research, testbeds and running networks. Neutral open access networks have flourished in completely different scenarios and for unrelated reasons. Nevertheless, there are some lessons to learn and maybe the neutral open access framework is the right approach for the networks of the future.

The discussion of openness and neutrality in the access network spans far beyond the purely technical issues, and has social, economic and regulatory implications. These last reasons will be the ones that ultimately determine the success or failure of the neutral open access paradigm.

However, from the purely technical point of view, neutral open access networks come with some advantages. In particular, the latest trends in wireless technology present performance improvements that are much more evident in wireless neutral open access networks.

The lack of inter-infrastructure barriers allow a much more efficient exploitation of the available resources such as channel time and spectrum. Better opportunities for dynamic resource assignment improve the overall performance of the network. Finally, the neutral and open access nature eases collaboration with relays and other terminals.

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