Bottom-up Broadband: Free Software Philosophy Applied to Networking Initiatives

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***Abstract*—This paper discusses open and free (libre) networks. The free software and open hardware movements are well established and known. Contrastingly, there is relatively little discussion on open/free network initiatives. Software, hardware and networks are closely knitted together and therefore it makes sense to explore open/free networks by establishing parallelisms with open/free software.**

The first part of this paper presents a classification of alternative models for network deployment, according to their degree of openness. Then we study the driving principles behind open/free networks to see that these principles are not that different from those found in free software development. The community-centered approach that has allowed the growth and the success of free software may also represent the key strength of open/free networks. We point out the advantages of the peer-to-peer production model found in the network communities. Finally, we introduce the Bottom-up Broadband project that has the goal to study and promote open/free networks.

I. Introduction

OPEN source is a way of creating and sharing software that has several advantages and areas of applicability. By publishing the source code instead of keeping it secret, a production model that relies on cooperation instead of competence is encouraged. Free software projects are often in hands of communities instead of corporations, and the skilled users have an opportunity to adapt them to their needs and shape the evolution of the software.

Both the open source software and the free software models are well accepted. We find these kinds of software running almost everywhere: personal computers, mobile phones, tablets, server farms and embedded devices.

In this paper we discuss the application of open source and free software development principles to network deployment. There is a whole spectrum of diversity between totally closed networks and free (libre) networks. We classify alternative models for network connectivity in three categories and provide examples for each of them.

We also discuss how the principles of community development have some advantages that make it possible to build better networks, or simply build networks that are not viable when using more closed approaches.

Then we introduce the *Bottom-up Broadband for Europe* initiative that has the goal of studying and promoting network deployments in which the users are active participants and not mere passive consumers. We use the term bottom-up to emphasize the fact that are the users the ones that take the initiative.

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II. A Classification of Alternative Network Models

Just as there are different models for software distribution, there are also different models for constructing a network. Alternatives for software distribution include shareware, open source, and free (libre) software. The three models that we define for alternative network deployment are: *shared Internet access*, *open access networks* and *free (libre) networks*. Examples are provided for each kind of network to illustrate the concepts.

These models can be compared or contrasted with what we call the top-down monolithically integrated model. The monolithically integrated model is simple: there is a telecom operator that owns the infrastructure and provides the service to a customer.

A. Shared Internet Access

Shared Internet access is not an open/free network. Nevertheless we include it in the present classification because it is a first step away from vertically integrated monolithical models. In shared Internet access, a person or entity that has Internet access in a given location sees an advantage in sharing it with someone else. This sharing can often result in a win-win situation for all the participants. We provide three examples of such sharing.

Eduroam is an international WiFi roaming service for members of education institutions. It is useful for visiting scholars and for students using libraries of different universities. All of them can use their home university credentials to access the Internet from the premises of any other affiliated institution. It is useful for the visitor and also for the host institution that benefits from the visit.

ProvinciaWifi is a WiFi service available in the province of Rome and other regions in Italy that offers WiFi access in public locations. Many commerces collaborate and share their own bandwidth with *ProvinciaWifi* to attract and retain customers. In this case, the commerces acquire an access point with ProvinciWifi's open firmware called *OpenWisp*, and *ProvinciaWifi* takes care of the user authentication according Italian law.

Finally, *FON* is an example of a business model built on collaboration. Collaborating members of *FON* install a *FON* access point to their Internet connection and share that connection with other users. This becomes a *FON* hotspot. The members of *FON* can connect to any of the millions of *FON* hotspots worldwide for free. Non-members can also connect, but they have to pay. *FON* has partnered with large

Telecom operators, such as *BT* and *Deutsche Telekom*, that have recognized the benefits of network sharing.

B. Open Access Networks

Open Access Networks present a layered model in which different service providers can share the same infrastructure. The participating entities agree in a set of rules that govern their collaboration. In a basic model [1], a *neutral operator* takes care of the infrastructure. Then, multiple service providers offer a services such as TV, telephone and Internet access over the shared open access network. The service providers use a share of their incomes to pay to the network operator for the common infrastructure.

This model represents savings for the service providers, as they can reach a large number of customers without incurring in costly infrastructure deployment. Furthermore, it lowers the entry barrier for new service providers and fosters competition and innovation. The users have a larger number of options to choose from and select the service providers that better adapt to their needs [2]. As it is easy for an user to switch from one service provider to another, the service providers have a good incentive to keep their customers happy. Happy customers spend more money on communication services which is, in turn, beneficial for the service providers.

In this model, the final users, house owners, the City Hall or other organizations may have interest in collaborating in the extension of the access network. A single investment in a neighborhood will provide the citizens with a diverse offering of services. Forzati et al. report that 95% of the municipality networks in Sweden operate according open access network models [3].

The neutral operator is in a privileged position as it owns the network that all the others ISPs need to use. Consequently, it is recommended that the neutral operator is a *for benefit* (not for profit) organization. The neutral operator should not be allowed to offer services to the final user, and should treat all service providers equally, following some agreed rules [1]. The service providers still operate under a market competition logic. Nevertheless, in spite of being competitors, the service providers need to collaborate to maintain the neutral operator.

C. Free (Libre) Networks

Free (libre) networks are the network equivalent of free (libre) software. They are community-oriented and governed by rules that emphasize freedom. *guifi.net* is an example initiative of a free network and operates according to four basic pillars:

- Freedom to use the network, as long the other users, the contents, and the network itself are respected.
- Freedom to learn the working details of network elements and the network as a whole. Freedom to disseminate the knowledge and the spirit of the network.
- Freedom to offer services and contents.
- By joining the network, the network is extended according to the previous principles.

There are other community networks operating under similar principles. *guifi.net* has the merit of having extended beyond the technical community and currently has 21,000 working nodes and is growing at a steady pace. This growth has been enabled by the development of automated tools to configure and manage the nodes. Another remarkable aspect is that *guifi.net* has evolved since its origins to embrace new technologies, such as optical fiber and dynamic wireless mesh solutions. Optical fiber offers gigabit per second speeds to the participants of the network and dynamic wireless mesh makes it possible to have out-of-the box quick network deployments.

Regarding funding, the wireless network has grown organically in a model in which the people that joins the network contributes with a new node. Crowdsourcing is used to pay for more ambitious actions that benefit many participants. Optical fiber deployment has been a new challenge in terms of funding, as the interested participants had to pay in advance to cover the cost of the deployment. A model similar to the open access network mentioned in the previous subsection has been adopted. Multiple service providers are allowed to operate over the common infrastructure and they have to collaborate in the deployment and maintenance of such infrastructure. Even though the users have to pay for the initial inversion, this fact is compensated by the lower monthly fees and the higher connection speed, which is currently 1 Gbps.

Interestingly, the bottom-up fiber deployment has occurred in a rural region to connect farms that otherwise could not enjoy network speeds parallel to those offered in the city. Even though the region was right next to a fiber backbone, the rural market was not attractive for traditional top-down operators. Top down vertically integrated operators prefer to focus their efforts on urban deployments which are more profitable. By changing the model from top-down to bottom-up, it was possible to offer a high quality service to the users and a business opportunity to small local ISPs.

The availability of broadband connection is a clear advantage for the development of the region and the presence of a free network in the area has positively impacted the digital inclusion indicators [4].

Bottom-up networking initiatives can be found almost everywhere. They start locally and sometimes organize themselves in larger entities. This is the case of the *FFDN* (Fédération French Data Network) that represents a joint effort of 21 small Do-It-Yourself Internet Service Providers. The *FFDN* promotes values such as network neutrality, transparency, user empowerment, volunteer contribution and community-driven initiatives.

III. Evolution and New Trends in Open Access

The move from closed networks to open/free networks does not happen overnight. It is a progressive change which connects with other opening processes, such a as the move towards free software or open data. Here we provide the view of the evolution towards free networks offered by the *Free Network Foundation* and also explain how open access sensor networks can be an enabler for open data.

A. Steps Towards a Global Free Network

The *Free Network Foundation* wiki describes that the transition towards a global free network is going to be progressive.

In a first step, neighbours will create a small network to share an Internet access. This is already quite common, as sharing makes it possible to take advantage of statistical multiplexing. Many users are not making an intense use the network the whole day and therefore they can save some money sharing the connexion.

In a second step, the participants that created a network to share Internet access start to offer services in the network. Network logging and monitoring servers, web servers, proxy servers, mailing lists, Internet Relay Chat Servers, blog servers and File Transfer Protocol servers are natural choices. At this point, the bottom-up broadband network is not only a content consumer. It is also a content provider.

The third step is to interconnect the bottom-up broadband islands using tunnels. And the fourth step is to deploy backbone links to replace the tunnels.

The final goal of the bottom-up broadband network should be to provide Internet access to anyone that is interested, to prevent that price barriers leave a fraction of the population without access to the Internet.

B. Open Sensory Data

An area that has been subject to intense research in the last years is sensor networks. This is still an emerging technology that promises to make it possible to gather large quantities of data that then can be used to make decisions or offer services.

The principles of openness can also be applied to sensor networks. There are initiatives, such as the *Air Quality Egg* or the *Smart Citizen Kit*, that embrace a community-driven solution in which open hardware and free software is used to create the network. These initiatives have the complicity of the hacker and do-it-yourself communities to adjust, refine and enhance the solutions. Importantly, the data is gathered and owned by the users that can choose to share it as open data for others to create applications and value on top of it.

IV. Peer-to-Peer Production Model

The peer-to-peer production model [5] relies on horizontal symmetric relations. It is in contrast to the hierarchical boss-to-subordinate model and the consumer-producer model. This model is well understood by the networking community as there is a large experience with peer-to-peer distributed applications in which the participating nodes take turns in assuming the roles of client and servers. In the networked applications realm, peer-to-peer offers advantages such as scalability and resilience, and also some challenges such as bootstraping or providing quality-of-service guarantees.

Peer-to-peer is also a form of organization for the people. There are examples of people collaborating as equals in the production of goods: the peer-to-peer production model. Open source development and the construction of the Wikipedia involve a large number of peers contributing in the creation of value. In fact, peer-to-peer models can be more effective than hierarchical models.

Even though all peers are in principle equal, not all the contributions necessarily are. It is normal that there are contributions of high value while others are of dubious value. In any case, the peer-to-peer production model is inclusive by definition and offers an opportunity to all of those acting in good faith. Even for those that have little to contribute, the peer-to-peer model offers the possibility of learning and being part of the project.

The peer-to-peer model relies on transparency and openness, ethical principles and good practices. These driving principles derive in what it has been termed *hyperproductivity*, in the sense that they are more effective than hierarchical models. The higher efficiency of peer production models may result in the progressive displacement and replacement of previous production models. The changes occur progressively and gradually. In the following we detail some specific aspects that characterize peer-to-peer models.

A. Throwing More Brains into the Project

The model of the *bazaar*, as opposed to the *cathedral* [6], emphasizes the communication with the users and their participation and collaboration in the development process. Having more people thinking and working for the project improves and speeds up the development. Moreover, by providing the users all the information about the network, it is possible for them to provide high-quality helpful feedback.

Another aspect is that building a network requires a large set of skills, including purchasing, installation, configuration, programming, design, financial, legal, etc. The person that is good at mounting a pole on top of the roof is not necessarily the one that has server administration skills. By having a large number of people involved, all the necessary skills can be covered by one or more of the participants.

Furthermore, people have the chance of doing what they like to do and what they are good at. The person that enjoys aligning antennas will probably be good at it and will do it with pleasure whenever it is needed. Someone else will prefer to prepare video tutorials. Ideally, everyone can find a way in which she can efficiently collaborate with the project. Giving the people the opportunity to decide in which way they want to collaborate is one of the key advantages of the peer-to-peer model compared to the top-down approach.

Letting people participate in the decision-making process and perform the tasks they are interested keeps the participants highly motivated, which also helps to improve the efficiency of the peer-to-peer model.

Working with pleasure does not necessarily mean working for free. The services to the community are intertwined with monetary payments that will allow the main contributors to devote more time to the peer-to-peer project and make a living out of it. These aspects are explored in the next subsection.

B. The Peer-to-Peer Economic Ecosystem

Bottom-up broadband initiatives normally begin with a purpose of social service. Quite often, the participants are interested in satisfying their own networking needs and those of their communities. It is not uncommon that each participant buys her own hardware to be part of the network. As the building of a data communication networks results in the

simultaneous construction of a network of trust, the participants team up and collaborate using crowdfunding schemes to buy equipment that is perceived to be beneficial for all. For the most ambitious initiatives, such as optical fiber networks, the participants need to reach an agreement and advance an important quantity of money to make the deployment possible. Sometimes, local authorities perceive that there is a value in supporting the deployment of networks and also contribute to these initiatives.

Even though the main motivation is not to make money out of the network, an economic ecosystem is created to support it. For instance, hardware merchants can specialize in selling the equipment that is needed for the network. Also installers have an opportunity to work for those users that cannot install and configure the equipment by themselves. This is specially critical in more complex deployments such as optical fiber networks. Finally, it is also possible to create companies that sell services, such as Internet access or TV on top of the bottom-up network. The result is that in addition to offering broadband to the users, the network also offers jobs and stimulates the local economy.

The companies around bottom-up deployments are leaded by local enterpreneurs, which also spend their money locally and in this way maintain the wealth of the community. The small companies that make a living out of the network have a good incentive to invest in such network, and therefore reinforce the bottom-up broadband initiative. Nevertheless, these companies operate in the frontier between the peer-to-peer economy and the market economy and tension and disputes arise. The companies are natural competitors but they have to invest in the same commons resource. It can be tempting for one company to stop investing in the network in order to obtain a competitive advantage over the other. However, this move can be perceived by the community as treachery. In this case the community may balance the situation by favoring the company that gives more to the network. This presents a delicate equilibrium that not always can resolve satisfactorily.

It is often the case that the participants agree in a contract and a set of rules intended to prevent any kind of abuse. Nevertheless, for the project to progress smoothly, it is important that the participants are as interested in contributing as they are in profiting from the network.

In the ideal case, the situation is not that different from the one existing in the open source ecosystem, in which there are companies that make a living out of open source and generously donate code or employees to the community in order to strengthen the ecosystem.

In the case of open sensor networks, a possible sustainability model is the selling of open hardware. This approach has already been successfully executed by open hardware designers and manufacturers, such as *Arduino* and *Raspberry*. The product is open hardware and therefore can benefit from the efforts and contributions of the community. At the same time, most people will prefer to buy the product rather than produce it themselves. The incomes originating from selling devices can be used to maintain a team of core developers and reinvest in improving the product.

C. From Scarcity to Abundance

In a market economy, the resources are scarce and therefore they can be sold to obtain the maximum profit. In an abundance economy, it is no longer possible to speculate with the goods as there are more goods than needed. In these economies, the goal of the participants is no longer to accumulate wealth, but to build up reputation. Reputation is obtained by giving gifts, and for this reasons this model also receives the name of gift-economy [7].

There is already a gift economy for Internet content. Photographers donate photos, programmers donate programs and bloggers donate articles. It works because there is a wealth of information and the users cannot consume it all. Users can receive without contributing, but still many participants decide to contribute because it *feels good*, and they like to participate in this reputation system in which those that contribute receive the recognition of the community. With digital goods, its easy to reach gift economies because the cost of replicating and distributing the goods is very low.

For network deployment, the situation is not that obvious. Still, it is not uncommon to find situations in which by contributing one node to the network, a participant receives much more than offers. These situations favor the transition to a gift-economy. The spirit of the gift economy is often present in bottom-up networks mailing lists and community gatherings, in which participants uninterestedly help each others in a continuous process of learning. The participants also contribute time for network trouble-shooting and planning, and also contribute connections to the Internet. These are gifts that the participants offer to the community.

V. The Bottom-up Broadband for Europe Initiative

The *Bottom-up Broadband for Europe* initiative studies and encourages bottom-up networking deployments. By bottom-up, we mean that there is a peer-to-peer ingredient and that the users play a more active role than mere passive consumers. The project has two differentiated goals. In the short term, the objective is to run experiments (called pilots) to learn about bottom-up initiatives, create awareness and interconnect disperse efforts. In a second stage of the project, the intention is to create a global community or umbrella organization that helps in promoting and coordinating the multitude of initiatives that are taking place.

Bottom-up Broadband for Europe tries to cover a wide range of pilots in terms of technologies being used, geographical location, funding model, number of users, etc. It also encourages the collaboration between students and experts and the preparation of profuse documentation that can help to repeat successes, avoid pitfalls, and guide policymakers.

We try to apply the same principles that make free libre software and free libre networks so successful. We run a public mailing list and everyone is invited to contribute and collaborate.

VI. Conclusion

In this paper we have discussed open/free networks and how they are similar to free software. The focus is placed on the

peer-to-peer organizational models that have shown to be at the same time flexible and effective. The clearest example of the success of this approach is the deployment of optical networks to interconnect farms in a rural area. Open/free networking is just a new way of building networks that encourages collaboration instead of competition. *Bottom-up Broadband for Europe* has been created to study, document and promote open/free networks with the ultimate goal of eradicating the digital divide. We are witnesses of a transformation in which the network users take a more active role. They participate and guide the creation and development of networks driven by social motivations.

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