

Navío-Marco, Julio; Arévalo-Aguirre, Adrian; Pérez-Leal, Raquel

Conference Paper

WiFi4EU: Techno-economic analysis of a key European Commission initiative for public connectivity

29th European Regional Conference of the International Telecommunications Society (ITS):
"Towards a Digital Future: Turning Technology into Markets?", Trento, Italy, 1st - 4th August, 2018

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Navío-Marco, Julio; Arévalo-Aguirre, Adrian; Pérez-Leal, Raquel (2018) : WiFi4EU: Techno-economic analysis of a key European Commission initiative for public connectivity, 29th European Regional Conference of the International Telecommunications Society (ITS): "Towards a Digital Future: Turning Technology into Markets?", Trento, Italy, 1st - 4th August, 2018, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/184973>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

WiFi4EU: Techno-economic analysis of a key European Commission initiative for public connectivity

Julio Navío-Marco.

Dept. of Management and Business Organization, UNED

jnavio@cee.uned.es

Adrian Arévalo-Aguirre

Spanish College of Telecommunication Engineering, COIT

aarevalo@coit.es

Raquel Pérez-Leal.

Dept. of Signal Theory and Communications, Univ. Carlos III de Madrid

rpleal@tsc.uc3m.es

ABSTRACT

This paper analyses the WiFi4EU initiative, the measures proposed by the European Commission (EC) to speed up public access to Wi-Fi throughout Europe in the coming years, ranging from rapid mechanisms to subsidising the infrastructure. We set out to analyse how these measures are incorporated into the EU policies for building a Digital Single Market and the EC's regulatory tradition, and what the impact of this initiative is likely to be. As this innovative initiative will have an effect upon the network deployments strategies of operators and countries and it has been drawn up in a climate of uncertainties and delays, the article puts all of this into the context of the current European regulation debate and conducts a techno-economic analysis to assess the expected impact of the initiative. We have observed a slight shift towards developmental models in the EC regulatory framework. Furthermore, the techno-economic analysis has revealed the limited extent of Community aid and the considerable variability of the equipment deployed and the expenditure involved. We have also highlighted the questionable formulation of the allocation mechanisms, and we have included certain examples or suggestions for optimisation.

Keywords: WiFi4EU, network deployment, EC regulation, DSM, municipality

1. INTRODUCTION

The “Wi-Fi for Europe” (WiFi4EU) initiative is a key part of the European “Gigabit Society” strategy aimed at promoting connectivity for all local communities in the EU Member States. The European Commission proposes an investment of €120 million from 2017 to 2019 to promote access to wireless connectivity in public places. Free Wi-Fi would then be available in parks, squares, libraries and public buildings to benefit citizens and institutions with a public mission. The European Commission (EC) for speeding up public access to Wi-Fi provides rapid mechanisms for requesting aid aimed at subsidising the infrastructure and the obligation to maintain the networks in service for at least 3 years. Municipalities (or equivalent local administration) are the potential beneficiaries of this aid.

This fresh EC approach, which as we will see, comes to fill (or re-open) certain regulatory gaps, contributes to the debate between two different approaches to ICT policy - a regulatory and a

developmental approach, and has a major impact both on the national regulatory strategies to promote connectivity and on the strategies of the municipalities involved in guarantee network infrastructures and digital services for the citizens (Picot & Wernick, 2007; Troulos & Maglaris, 2011; Rajabiun & Middleton, 2015). This free-of-charge local wireless connectivity without discriminatory conditions could make a major contribution to bridging the digital gap, especially in communities that are lagging behind in terms of digital literacy, including rural areas and remote locations, which makes it well worth a detailed study.

Therefore, in the light of this novel initiative, this paper has a twofold purpose: firstly, to assess the regulatory implications of the WiFi4EU initiative, trying to understand the relationships and impact on EC policies and its regulatory tradition to build a Digital Single Market, and secondly, to assess, through a techno-economic analysis, the influence that this initiative has on real connectivity in Europe, and the development of digital capabilities for EU citizens. The ultimate aim is to find out how efficient could be in connectivity promotion and in cost term, and to propose specific actions to optimise the effect of this key European initiative. This is the first piece of research work devoted exclusively to analysing this WiFi4EU EC initiative, and to provide a holistic and comprehensive view of its impact and effectiveness.

This study comprises five sections. After Section 1, the Introduction, Section 2 establishes the theoretical framework by presenting WiFi4EU's background and a description, plus the implications for EC policies. Section 3 includes the techno-economic analysis and discusses the findings extracted from this analysis. Finally, Section 4 contains the paper's conclusions and its political and economic implications, as well as its limitations and future avenues of research.

2. THEORETICAL FRAMEWORK

2.1. WiFi4EU background and description

The European Commission did not have a common strategy to promote access to wireless connectivity throughout the EU. Neither was there a strategy aimed at increasing the participation of local communities in the Digital Single Market. Initiatives promoting free Wi-Fi connections were fragmented at best, and therefore deemed inefficient by the European Commission. Currently, efforts are still not coordinated at EU level, and there is no EU finance available for this kind of initiative.

However, in 2016 the Commission outlined its vision for a European Gigabit Society. The Commission's communication, "Connectivity for a competitive digital single market - Towards a European Gigabit Society" (European Commission, 2016), detecting a fragmentation of the communications markets along national borders and points to the fact that the deployment of very high capacity networks is difficult under the current regulatory framework. A series of initiatives were proposed: 1) a European electronic communications code (the code), which replaces four existing directives and aims to reform the framework for electronic communications, 2) an amended Body of European Regulators for Electronic Communications (BEREC) regulation which aims to foster cooperation between national regulators, 3) an action plan on 5G connectivity, which aims to boost deployment of the next generation mobile network, and 4) the 'Wi-Fi for Europe' initiative.

The Parliament, in its resolution "Towards a digital single market" dated 19 January 2016, also recognised the beneficial role of the Digital Single Market for the economy, for the integrity of

the market, and for the preservation of economic and social cohesion. The position of the European Parliament has invariably been in favour of promoting public Wi-Fi initiatives and has given strong support to WiFi4EU. Its resolution 2017/1953, not only provides a clear idea of its commitment and support, but also serves as an interesting and synthetic summary of the regulatory precedents:

“(6) In light of the Commission's communication of 14 September 2016 and in order to promote digital inclusion, the Union should support the provision of high-quality local wireless connectivity that is free of charge and without discriminatory conditions in centres of local public life, including outdoor spaces accessible to the general public. Such support is not covered by Regulation (EU) No 1316/2013 or (EU) No 283/2014 of the European Parliament and of the Council. (7) Such support should encourage public sector bodies, as defined in Directive (EU) 2016/2102 of the European Parliament and of the Council, to offer local wireless connectivity that is free of charge and without discriminatory conditions as an ancillary service to their public mission so as to ensure that people in local communities can benefit from high-speed broadband and have the opportunity to improve their digital skills in centres of public life. Such bodies could include municipalities, associations formed by municipalities, other local public authorities and institutions, libraries and hospitals. (8) Local wireless connectivity that is free of charge and without discriminatory conditions could contribute to bridging the digital divide, especially in communities that lag behind in terms of digital literacy, including in rural areas and remote locations.” (European Parliament, 2017, p.2)

The WiFi4EU call for applications works in the following manner: The Wi-Fi hot spots can be installed by the municipality using a voucher from the EU of €15,000 per municipality. The WiFi4EU scheme will be disbursed in a geographically balanced manner, so that high-speed connections can benefit both residents and visitors of thousands of local communities across the EU - at least 6,000 to 8,000 local communities by end of 2019. It will fund the equipment and installation costs (internet access points), while the benefitting municipalities will pay for the connectivity (internet subscription) maintenance and operation, keeping those facilities and equipment in a good state of repair for 3 years. The municipalities will be selected on a first-come, first-serve basis. A minimum of 15 vouchers per country will be awarded under the first call. The number of vouchers per country should not exceed 8% of the first call's budget. The initiative was eventually launched in March 2018, after a series of delays¹.

2.2. Implications for the EC policies

This initiative, which is considered to be an EC flagship initiative for providing connectivity to citizens, has major implications. How the initiative fits in with other EU policies and its regulatory impact is detailed below:

a) It contributes to the debate between two different approaches to ICT policy - a regulatory and a developmental approach (Picot & Wernick, 2007; Troulos & Maglaris, 2011; Rajabiun & Middleton, 2015):

¹ More than 18,000 municipalities, around a quarter of all in Europe, expressed their interest. A first call for applications was launched on 15 May 2018. Within seconds, over 5,000 municipalities had already applied and, within a few hours, 11,000 had done so. A few hours later, the Commission identified a flaw in the software supplied by contractors. This issue allowed some municipalities to apply in good faith before the call was opened. On 14 June 2018 Commissioner Mariya Gabriel, in charge of the Digital Economy and Society, cancelled the first call for applications for free Wi-Fi vouchers. The portal will re-open before the next call in autumn 2018, once the IT problems have been fully resolved. The EC considers that the allocation of the first vouchers was already planned to take place after the summer, therefore the current issue has not caused significant delay to the program. The vouchers from this first round of applications will be added to the budget for the next call.

The objective of a regulatory approach is to create a stable policy framework for a liberalised telecom market with real competition. The instruments in this approach are rulemaking and correction of market failures. However, there should be no direct market intervention. Moreover, the developmental approach tries to encourage investments and the use of ICT through various public-sector activities. The instruments include policies that are more intrusive than those applied in the regulatory approach (Falch, 2007). These could be public investments.

The EC is in general more sympathetic towards a regulatory approach in the field of network investment and connectivity (Falch, 2007), although it is currently adopting a broader approach, including the entire ICT ecosystem. According to Melody (2013), the regulatory instruments used have proved to be insufficient to facilitate the development of broadband infrastructures at an acceptable rate, and many countries are searching for alternative policy instruments (Falch, 2007). According to (Galperin, Mariscal, & Vicens, 2013) a similar trend can be observed in Latin America; moreover, there are states like South Korea, which show a clear preference for developmental model (Lemstra & Melody, 2014; Falch and Henten, 2010). Now, public support is seen not only as being responsible for the regulatory framework where market forces thrive, but also as the main force behind infrastructure deployment and innovative boosting measure (Feijoo Gonzalez, Gómez Barroso & Bohlin, 2011).

This fact is particularly important when one observes that the degree of infrastructure sharing and access can stimulate competition differently, especially when infrastructures overlap, and given that the essential facility doctrine has been intensively applied to public involvement in telecommunications (Nucciarelli, Sadowski & Ruhle, 2014).

b) It needs to be consistent with the national regulatory frameworks, which primarily address vertical integrated incumbents and nationwide markets, and it may need adjustments:

Wfi4EU has resuscitated the debate about who should lead these types of pro-citizen initiatives. This debate is already a classic (Massaro, 2017) and dates back to the 50s and 60s, the experts basically being divided between neo-functionalists, defending supranational interests, and the intergovernmentalists that stress the importance of the bargaining power of the EU Member States as a driver in the process of EU integration (Pollack, 2005; Moga, 2009; Rosamond, 2000). Currently, Multi-level governance has become one of the concepts most widely used to describe the EU system, emphasising the multiplicity of actors at different levels involved in EU activities (De Waele, & Kuipers 2013; Massaro, 2017).

EU Member States are using an array of public policy instruments to improve broadband availability and are taking steps to make these improvements in a variety of different ways as there is no one single European policy to promote broadband (Cava-Ferreruela & Alabau-Munoz, 2005). A great number of initiatives have emerged to achieve the coverage targets set by the Digital Agenda (Gerli et al., 2017). In 2009, the European Commission also adopted Guidelines for State Aid in broadband markets to ensure that public interventions in this market are permitted. Moreover, the fact that local and central governments have been actively supporting the supply of NGA networks where the market has failed to provide superfast broadband access (Cave & Martin, 2010). Limbach, Kübel & Zarnekow (2014) also means that a close examination ought to be given to the question of whether decisions concerning municipal involvement should be made on a local or national level.

The controversy can also be seen in private vs. public terms: leading Asian countries in broadband speed have reached their broadband targets with a considerable degree of public involvement (Picot and Wernick 2007), while the European Union aims to unfold market forces at different layers in an unbundled telecommunication value chain. Despite the controversy, empirical research into the matter is rare and usually focus on country comparisons (Troulos and Maglaris, 2011), opening new opportunities for further research.

c) It needs to conciliate with municipal plans for large scale broadband development and alternative infrastructure providers that may also contribute to network developments (Gerli, Van der Wee, Verbrugge & Whalley, 2017):

The literature shows several examples of networks with municipal involvement (i.e. Amsterdam in Wagter, 2010, cities in Spain in Ramos, Arcos, & Armuña, 2009, Nuenen in Sadowski et al., 2009), the operators' impulse (Van Kranenburg & Hagedoorn, 2008; Huigen & Cave, 2008) and also examples of new agents such as utilities (e.g. Gillett, Lehr, and Osorio, 2006, Tadayoni & Sigurðsson, 2007). The concern for deployment also applies to rural areas (Wood, 2008, Tookey, Whalley, and Howick, 2006, Lattemann, et al., 2006) where community-led initiatives or community initiatives began being used (Shortall, 2004; Skerratt, 2010; Skerratt and Steiner, 2013) that have also found new ways of financing the deployments and original models. In this context WiFi4EU appears as yet another piece in the puzzle with all the other actors and it is worth analysing how it is fitting into this diverse scenario of initiatives and stakeholders.

3. TECHNICAL-ECONOMIC ANALYSIS AND DISCUSSION

In this section we perform a complete technical-economic analysis based on the development of typified scenarios and the technical design of the solution. This enquiry give us a quantitative view of how much aid and what funds are being provided for each community, all of which help us to assess their effectiveness. In this sense, the method of analysis consists of two distinct phases: a) the technical analysis and b) the economic analysis based on the technical solution, plus the discussion that embrace both phases.

The technical analysis comprises different steps: 1) The selection of possible technical scenarios in accordance with the Wi-Fi standards, 2) The matching of scenarios with the possible use cases defined by the WiFi4EU initiative. In the light of these steps, the economic analysis consists of: 1) The cost analysis, 2) optimising the cost of the recommended solution and 3) studying how to maximise the impact of the initiative.

“The main centres of public life” proposed by the EC² are taken as the basis for preparing deployment type scenarios. To be specific, a Wi-Fi network is deployed in a park, inside a municipal building and in a public square. In the last of these three cases two types are considered: medium-low and high density.

First of all, it is performed a coverage technical analysis, in which the main elements of the architecture of a Wi-Fi network are established, together with a description of the technical characteristics of the equipment. That will be subsequently utilised in the economic analysis of

² <https://ec.europa.eu/digital-single-market/en/policies/wifi4eu-free-wi-fi-europeans>

the different scenarios considered. Then, some reflections upon the findings from both studies are discussed.

3.1. Technical analysis of coverage

This section contains certain general considerations about the architecture for a Wi-Fi network, together with a brief analysis of design that enables us to establish on the basis of the characteristics of the equipment, the coverage ratio and the logical capacity of users for each scenario.

Before drawing up the diagram for the system and its constituent elements, it must be pointed out that the networks to be deployed in this project will be networks with basic service (BSS)³ or with extended service (ESS)⁴ infrastructure. Therefore, they will require interconnection equipment through which all the network traffic passes, known as the access point (AP) or hotspot. This is the main connection mode for permanent Wi-Fi networks, especially in residential zones, offices, public environments, etc. The network can rely on one or more APs depending on the service type (the BSS has one AP, and the ESS, has several), constituting a point-to-multipoint network and a multipoint-to-multipoint network, respectively.

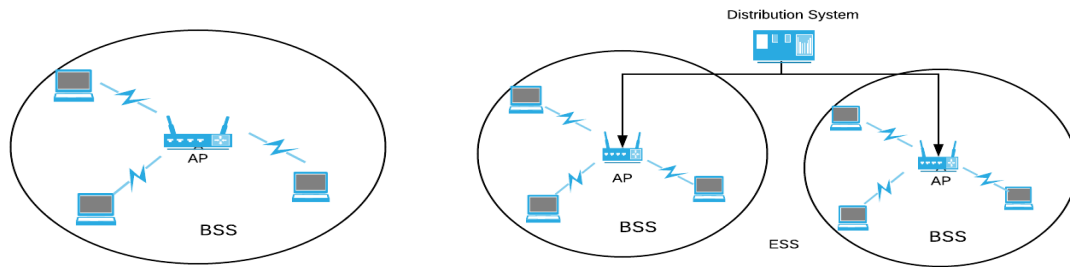


Figure 1 Wi-Fi Networks. Infrastructure architecture. BSS y ESS

Therefore, the network architecture is composed of the following elements and its main functions (see figure 2, and extended details in Appendix 1) :

- **Access Point, ‘AP’ or hotspot.** APs are responsible for receiving via the radiofrequency waves (RF), the information from the various devices and for passing it on, as well as for serving as an interconnection point with the access network
- **User terminals,** User terminals are generally items of equipment that have a wireless adapter that complies with Standard IEEE 802.11 and that enables to be connected to the wireless network. This is usually the case, given that access points generally implement Standard IEEE 802.11n, and the most recent ones, also implement Standard IEEE802.11ac. APs that support Standard 802.11n are compatible with the IEEE 802.11a/b/g/n devices, i.e., with those of the same standard and with all the old equipment. APs that implement Standard 802.11ac, are inherently compatible with IEEE 802.11a/ac devices, although in practice, they are also compatible with the rest of the standards, in 2.4 GHz but also in 5 GHz.

³ BSS: Basic Service Set

⁴ ESS: Extended Service Set

- **AP controller**, which makes it possible to centrally manage all the APs
- **Load balancer**, which makes it possible to distribute the different requests on a wired Local Area Network (LAN) via the different Wide Area Networks (WAN) connectivity ports provided by the ISP.
- **Wi-Fi repeaters/amplifiers or network extenders**, a device that receives the signal from an AP node, amplifies it and retransmits it managing to increase the signal level in the zone, without a new AP having to be installed (which would otherwise increase the cost).
- **Access control, firewall and other network equipment/functions**. There are other functions that can be taken on by other equipment, such as user validation and control via a RADIUS server, a server for virtual private networks (VPN), the firewall, etc., although currently the trend is for one single item of equipment to perform most of these functions, or even for some of these functions to be virtualised in a server connected to the cloud.

With a view to calculating the cost of all the equipment in the subsequent economic analysis, we have considered as active equipment for this general network architecture, the equipment at the access points (AP), a network controller that acts as a router, AP controller, user control, Firewall, Proxy server, as constituting one single “smart” network element, together with a PoE⁵ injector, which provides the power supply for all the items of network equipment via the Ethernet cable. Not only link parameters (transmission capacity and sensitivity required for a particular binary transmission rate) but also the characteristics of the equipment (gain, vertical/horizontal antenna opening, etc.) can be established from the equipment characteristics sheets of the three leading sellers. Such data, together with the habitual restriction of the capacity emitted from each one of the bands (typically 2.4 and 5.8 GHz), enable us to establish the transmission and final reception capacity that will be used for the link calculation.

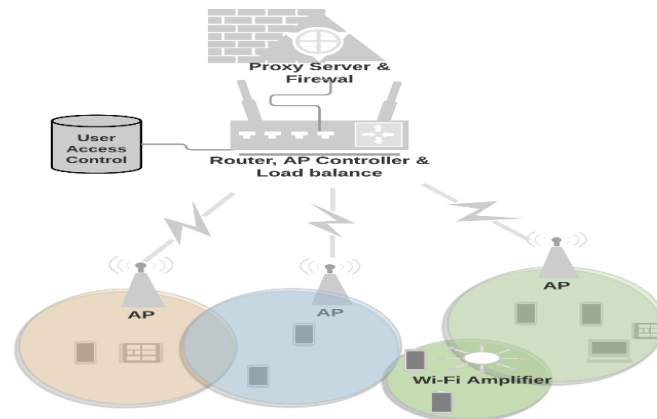


Figure 2. Network architecture

Outdoor propagation it is assumed to be free of obstructions with a safety margin of 15 dB was used to make the calculations. When deploying indoors, and given that the structural characteristics of the propagation environment where the network is located vary greatly, the data have been extrapolated from a well-planned network that has already been deployed. However, these standard scenarios are a first approximation that necessarily had to be completed with an

⁵ PoE: Power over Ethernet

initial survey and a radio-electrical planning study in each case, in order to prevent oversized and non-optimised deployments.

Friis's formula (Johnson, 1984; Friis, 1946) was used to calculate the outdoor link balance, in logarithmic units, and adding a safety margin (MS) that considers the potential losses (affecting cables, through connectors, interference, absorption), and the following expression is obtained:

$$P_{Rx}(dBm) = P_{Tx}(dBm) + G_{Tx}(dB) + G_{Rx}(dB) + 20 \log\left(\frac{\lambda}{4\pi D}\right) - MS (dB) \quad (1)$$

where P_{Tx} and P_{Rx} represent the power transmitted and received, respectively, G_{Tx} and G_{Rx} represent the transmitter and receiver antenna gains, respectively and the term $\left(\frac{\lambda}{4\pi D}\right)^2$ represents the path losses, where λ is the wavelength for the selected transmission frequency and D is the distance between the transmitter and receiver.

The maximum cell radius is obtained by calculating the maximum distance between the transmitter and the receiver in the Friis formula, for the transmission power and sensitivity for a particular binary rate. It is possible to calculate the associated cross section area in m^2 , using this parameter and the antenna aperture. Table 1 shows a comparison between the binary rate and the maximum cell radius, together with the associated cross section area, provided by the Wi-Fi access equipment most extensively utilised by three of the world leaders on the market.

AP Model	Binary rate (Mbps/node)	Max. cell radius (m)	Associated cross section area (m^2)
Vendor 1	300	50	408
Vendor 2	900	47	360
Vendor 3	200	60	244

Table 1. Final results for the speed, distance and cell coverage area for the various AP models. The selected vendors are top international suppliers of these infrastructures.

This data shows that the various equipment models offer different binary rate characteristics and cover areas, allowing for a larger or smaller density of users by access point on the basis of the cell ratio. This information can be used to estimate the number of access points required to cover a target area, taking into account an overlap of 30% between cells, which is typical in wireless network deployment. The logical capacity of users at the maximum rate and the average rate has also been estimated. The maximum theoretical capacity calculated under the hypothesis that all the users consume the maximum rate (30 Mbps) all the time, which hardly ever happens. The average rate is calculated assuming that all the users consume a lower average (3 Mbps), respectively, even if they do have available the maximum rate required by the European Commission for deployed networks, which is more realistic, not only because of the use that the user makes, but also because of the device itself. A typical area to be covered has been proposed for all the scenarios, albeit one that is completely scalable to the target area where the Wi-Fi service is to be provided. The findings for this design can be seen in the first section of Table 2.

3.2. Economic analysis of the different standard scenarios

Related to the capital expenditures (CAPEX), the AP cost and the cost associated with the active equipment defined in the architecture has been considered when conducting the associated economic analysis. Furthermore, certain extra main elements have to be valued, including an Ethernet supply injector (PoE), wiring and supports.

Several market leaders have been consulted in order to find out the cost, and these manufacturers have provided the cost of the active equipment, moreover there is a fixed cost for wiring and supports budgeted at 123 €/node and a variable cost amounting to 60% of the cost of the active equipment for the labour charges involved in installation work, plus a configuration cost that comes to half the installation cost.

Three basic expenditures have been taken into consideration when it comes to assessing the normal network operating costs: the physical and logical maintenance of the facilities, customer support and the expense involved in subscribing the connectivity service to the Internet with an ISP⁶. The maintenance cost is assimilated with the amortization percentage of the installed equipment, which has an estimated duration of 8 years. The estimate for customer support has taken into consideration contracting a server in the dynamic demand management cloud at an average price of 1.6€/ per user and year up to 1,000 users, 1.2€/ per user and year between 1,000 and 1,500 users and 0.8€/ per user and year for over 4,000 users. It is assumed that the cost of connectivity to the Internet will be equivalent to contracting an FTTH connection for a standard commercial residential rate, i.e. 62.5 € per month.

The percentage of the project to be financed by the European Commission is obtained by estimating the capital expenditure infrastructure installation investment cost, which will be sponsored by the European Commission, together with the normal operating expenditure (OPEX) for the first 3 years, which will be met by the applying Local Authority. It is estimated that the EC will be responsible for 30-45% of the final cost of the project, depending on the deployment scenario.

On the other hand, the maximum number of sites per scenario typology has also been calculated and, in this case, what expenditure will have to be met by the European Commission and the applying Authority out of the total cost of the aid for the project. Once again, the percentage of the project financed by the Commission is calculated, in this case, applying a reduction of 33.33%⁷ to the normal running cost, thanks to the synergies between the networks that are deployed in a municipality.

Finally, two comparative parameters are included on the basis of the monthly cost per user and related to the cost per m² of service offered, which will enable us to compare the cost in different scenarios. Table 2 gives a detailed comparative breakdown of all the findings, regarding both the

⁶ The estimated cost is a commercial cost based upon enquiries made to different manufacturers and installers of Wi-Fi networks, with whom there is a guarantee that they will correctly implement the facilities and provide reliable quotes for the envisaged networks. However, as happens with most case of network deployment, there may be synergies between networks deployed in one single territory or even on a national scale, such as, for example, when it comes to giving support to customers, or if they share the network maintenance cost, which could be subcontracted to the same company that installs the infrastructure, which is a way of reducing operating costs.

⁷ It is an estimated percentage, assuming that 2 out of 3 networks that are deployed in a municipality can share some of the Normal Running costs (user platform, connectivity, etc.) to be close to each other

technical design and the economic appraisal, for the various scenarios being considered and the initial estimate of the cost involved in deploying Wi-Fi networks.

	Park	Public Square		Municipal Indoor
	Standard Park	Average Density	High Density	School
Associated surface area (m2)	2291	1309	1214	3410
Capacity of users connected and active at an average rate (3Mbps)	500	200	1350	1100
Capacity of users connected and active at a maximum rate (30Mbps)	50	20	90	110
Number of Reference Aps	5	2	3	14
Investment in installing the Infrastructures (CAPEX)	2,572.00 €	1,291.00 €	8,669.00 €	5,151.00 €
Active Equipment	1,030.00 €	550.00 €	7,310.00 €	1,910.00 €
Access Points	800.00 €	320.00 €	7080.00 €	1680.00 €
Network Controller	200.00 €	200.00 €	200.00 €	200.00 €
PoE Injector	30.00 €	30.00 €	30.00 €	30.00 €
Wiring and Passive Support	615.00 €	246.00 €	369.00 €	1.722.00 €
Labour Charges for Installing	618.00 €	330.00 €	660.00 €	1.146.00 €
Labour Charges for Configuration	309.00 €	165.00 €	330.00 €	573.00 €
Normal Running Expenditure Associated (3 years) (OPEX)	8,014.50 €	4,654.13 €	10,900.88 €	14,261.63 €
Physical & Logical Maintenance	964.50 €	484.13 €	3,250.88 €	1,931.63 €
Customer support	4,800.00 €	1,920.00 €	5,400.00 €	10,080.00 €
Connectivity	2,250.00 €	2,250.00 €	2,250.00 €	2,250.00 €
Investment + Normal Expenditure in the Period	10,586.50 €	5,945.13 €	19,569.88 €	19,412.63 €
Percentage of financing out of the total service cost	24.30 %	21.72 %	44.30 %	26.53 %
Number of spaces of this type that can be applied for	5	11	1	2
Further expenditure to be paid for by the developer according to the aid amount	26,715.00 €	34,130.25 €	7,267.25 €	19,015.50 €
Expenditure paid for by the European Commission	12,860.00 €	14,201.00 €	8,669.00 €	10,302.00 €
Percentage of financing of the total cost of the service (with synergies, supposing that max. num. of spaces are deployed).	32.50%	29.38%	54.40%	35.14%
Price/month per user at maximum rate	5.88 €	8.26 €	6.04 €	4.90 €
Price/month per user at average rate	0.59 €	0.83 €	0.04 €	0.49 €
Price/month per m² of service offered	0.13 €	0.13 €	0.45 €	0,16 €

Table 2. Comparison between the different scenarios.

The various scenarios considered are scalable to many zones covering a variety of surface areas and with different levels of user demand.

3.3 Discussion

The final cost for each Wi-Fi network that is displayed will largely depend on the general characteristics of the standard scenario developed and, albeit to a lesser extent, on the network characteristics (distribution, construction materials used at the site, user density, effects of other electronic communication networks, etc.), which it will be possible to consider thanks to an initial survey of the site and an in-situ radio-electric study.

It can be seen that the active equipment of the network is relatively cheap (especially with regard to access points), especially when compared to the cost of installing and configuring the equipment. The only exception would be the high-density public square deployment, where

equipment is been selected to withstand a high density of users, which makes it 15 times more expensive than the equipment at the other access points. In general, it can be demonstrated that there is a wide range of Wi-Fi equipment available, which means that it can adapt, in both cost and benefit, to the specific deployment requirements of nearly all the scenarios that there might be.

The scenario with the lowest deployment cost is a medium-low density public square, which is 3 times cheaper than the most expensive scenario, i.e., the high-density public square. This difference in cost means differences in the number of spaces of a particular type that can be deployed, e.g. only 1 space of the most expensive type can be deployed by the Local Authority, whereas 11 can be deployed in the case of low-density public square scenarios. It can be observed that this network deployed inside covers a greater surface area with almost 3 times as many users than one deployed in a medium-low density square.

The different degrees of financing for the deployments envisaged by the European Commission can also be seen, the percentage ranging from 30 to 50% of the total cost of the project, depending on the scenario. In this sense, Local Councils will have to make an economic effort that enables them to carry out operating and maintenance work to recoup the cost and make the project a success.

Finally, if we consider the monthly cost per user, we can see how the networks with few nodes are considerable more costly than the deployments with a greater number of nodes, although this eventually has to be compared with the actual number of network users, not with the envisaged capacity. As was only to be expected, the cost per m² of service is less with the deployment of lower-capacity equipment when compared to high-capacity equipment, which by contrast manage to achieve a lower cost per user at the maximum rate. As a general rule, the deployment cost is greater inside buildings than in the open air. However, as has already been demonstrated, deployments with comparable costs can be attained as long as a suitable survey is undertaken and proper radio-electrical planning is carried out.

Another question to be taken into account is the award procedure, for the purpose of which the EC originally considered a “first in, first to get” system, which does not appear to be the most suitable when public aid is involved, because the award should not be determined by order of application but by the objective to be achieved. As a result, the EC established a series of additional restrictions in addition to the original distribution of funds that was going to be determined exclusively by order of arrival. These restrictions included allocating a minimum of 15 vouchers and a maximum of 8% of the funds per applicant country (this first call involved allocating the first 1,000 vouchers, equivalent to a minimum of 225,000 € per country, and a maximum of 1,200,000 € or 80 vouchers).

Where voucher allocation is concerned, several recommendations can be considered aimed at improving the sharing out of funds and maximising the impact of the initiative in Europe: for example, to regulate the distribution in accordance with some kind of connectivity index or parameter such as the DESI⁸ or by carrying out a suitable optimisation exercise in fund distribution.

⁸ Digital Economy and Society Index (DESI). Countries like the Netherlands, Belgium and Luxembourg have better connectivity than the average for Europe and even much better than countries like Croatia, Greece and Bulgaria. Allocating more funds to the countries with poorer connectivity will achieve, a priori, what is being sought, i.e. a greater impact of the initiative on encouraging local connectivity, because it is precisely these countries where the inhabitants

With a view to this, and using the preliminary analysis data, we include, by way of example, an idea of the number of scenarios to be deployed to maximise the population covered with the minimum amount contained in the first aid call, i.e., those 15 vouchers of up to 15,000 € that are guaranteed for every applicant country. The following linear optimisation problem has been formulated in order to prepare this recommendation:

Maximise the total population covered, as long as they apply for 15 vouchers and that the cost per unit/project cannot exceed 15,000 €. What is also guaranteed is that all the deployments include at least one low-density public square, one park is completed in half of them, and that indoor cover for a municipal building is provided in one third of them. Finally, to guarantee minimum deployment for all the scenarios, a restriction has been imposed that requires cover for at least one high-density public square for every ten average-density squares.

$$\text{Max } (p_1 \cdot x_1 + p_2 \cdot x_2 + p_3 \cdot x_3 + p_4 \cdot x_4) \quad (2)$$

$$\text{s. t. } c_1 \cdot x_1 + c_2 \cdot x_2 + c_3 \cdot x_3 + c_4 \cdot x_4 \leq 15 \times 15,000 \text{ €}$$

$$x_1 \geq x_i$$

$$2 \cdot x_2 \geq x_1$$

$$3 \cdot x_3 \geq x_1$$

$$10 \cdot x_4 \geq x_1$$

where x_i , is the number of scenarios for each type (1: average-density public square, 2: Park, 3: indoor municipal building and 4: high-density public square), p_i , represents the population covered by each scenario type and c_i considers the cost associated with each scenario type.

The solution, obtained using linear optimisation software (LPSolveIDE-5.5.2.0), considers all the funds guaranteed per applicant country (225,000 €, 15 vouchers worth 15,000 €), is as follows:

- 43 average-density public squares,
- 22 parks,
- 14 indoor municipal buildings,
- 5 high-density public squares,

covering a total of approximately 41,750 people.

The total number of scenarios can be distributed between the 15 municipalities in proportion to their populations and/or specific needs.

5. CONCLUSIONS

Operators opposing public involvement in infrastructure development argue that public interventionism will stifle private investments and distort market conditions and innovation dynamics, while proponents of municipal broadband proclaim the benefits of the long-term economic spill-over effects of broadband to the local communities and businesses (Troulos & Maglaris, 2011). Additionally, when designing regulation, a choice is to be made between

are increasingly demanding these services, because they have a more limited range of other supplementary or alternative products.

centralised and decentralised regulatory structures (Senn, 2005). In the EU, such a choice has an impact on the distribution of powers between EU and national institutions (Cave & Webb, 2015).

In this context, the WiFi4EU initiative is a genuine and original measure that suggests the EC has taken a developmental approach to the most time-honoured regulatory tradition but with limited effect. As we have seen, it is more a political initiative than a high-impact instrument, and in some ways it could cause confusion in the complex scenario of both public and private stakeholders with interest in deploying these types of infrastructures. The controversy is served.

In the technical-economic analysis, we have noted the limited scope of Community aid (which requires major further effort from Local Councils) and considerable variability of the equipment deployed and expenditure, which means Local Councils have to plan in great detail if they wish to make optimum use of the Community aid giving the best service to their citizens. It is often the case (small councils or rural areas, for example) that more expertise is required with telecommunications networks, and municipal civil servants frequently lack such skills. We have also brought to light the fact that the allocation mechanisms could be improved, and we have provided an example or suggestion for optimisation, in an endeavour to maximise the impact of this EC instrument.

Initial findings from the study have enabled us to make recommendations for the best deployment, maximising fund usage, especially in small municipalities, and we are currently working on a more elaborated economical optimization to guarantee the best application of the EU funds. More precise recommendations are required to help municipalities in a task that, as we have detected, has many variants and needs specialist knowledge for both technical planning and regarding the regulatory framework. Finally, the study has allowed us to make some recommendations for policymakers, in view of the fact that the findings from the techno-economic analysis enabled us to suggest improvements for future WiFi4EU instrument calls, especially considering that public involvement and public-private partnering for the deployment of next generation infrastructures in telecommunications will require an integrated policy approach. (Gomez-Barroso & Feijoo, 2009).

Our analysis undoubtedly has its limitations, one of the major ones being the exploratory nature of the study, because the EC initiative that we are examining is still at a very early introductory phase. What we have done is more of an *ex ante* assessment in view of the delays affecting the initiative. However, this will permit us to draw comparisons when the awards and deployments start to progress. Furthermore, this paper also provides useful insights into the effectiveness of one of the key EC connectivity initiatives of the moment. Monitoring the economic aspect of the initiative and encouraging the deployment of infrastructures, as regards its originality and innovativeness in the field of regulation in the telecommunications sector, constitutes an interesting new research area that we intend to tackle in future work.

BIBLIOGRAPHY

Cava-Ferreruela, I., & Alabau-Munoz, A. (2006). Broadband policy assessment: a cross-national empirical analysis. *Telecommunications Policy*, 30(8–9), 445–463.

- Cave, M., & Martin, I. (2010). Motives and means for public investment in nationwide next generation networks. *Telecommunications Policy*, 34(9), 505-512.
- Cave, M. & Webb, W. (2015). *Spectrum Management. Using the Airwaves for Maximum Social and Economic Benefit*. Cambridge: Cambridge University Press.
- De Waele, H., & Kuipers, J. J. (2013). *The European Union's emerging international identity: views from the global arena*. Leiden: Martinus Nijhoff Publishers.
- European Commission (2016) Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions COM/2016/0587 final
- European Parliament (2017). Regulation (EU) 2017/1953 of the European Parliament and of the Council of 25 October 2017 amending Regulations (EU) No 1316/2013 and (EU) No 283/2014 as regards the promotion of internet connectivity in local communities.
- Falch, M., & Henten, A. (2017). Dimensions of broadband policies and developments. *Telecommunications Policy*. IN PRESS <https://doi.org/10.1016/j.telpol.2017.11.004>
- Feijoo Gonzalez, C. A., Gómez Barroso, J. L., & Bohlin, E. (2011). Public support for the deployment of next generation access networks-Common themes, methodological caveats and further research. *Telecommunications Policy*, 35(9-10), 791-793.
- Friis, H.T. (1946). *A Note on a Simple Transmission Formula*. IRE Proc., 254–256.
- Galperin, H., Mariscal, J., & Vicens, M. F. (2013). One goal, different strategies: an analysis of national broadband plans in Latin America. *info*, 15(3), 25-38
- Gerli, P., Van der Wee, M., Verbrugge, S., & Whalley, J. (2017). *The involvement of utilities in the development of broadband infrastructure: A comparison of EU case studies*. 28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, July 30 - August 2, 2017.
- Gillett, S., Lehr, W., & Osorio, C. (2006). Municipal electric utilities' role in telecommunications services. *Telecommunications Policy*, 30(7–8), 464–480.
- Gomez-Barroso, J. L., & Feijoo, C. (2009). Policy tools for public involvement in the deployment of next generation communications. *info*, 11(6), 3-13.
- Huigen, J., & Cave, M. (2008). Regulation and the promotion of investment in next generation networks—A European dilemma. *Telecommunications Policy*, 32(11), 713–721.
- Johnson, R. (1984). *Antenna Engineering Handbook (2nd ed.)*. New York: McGraw-Hill.
- Lattemann, C., Kupke, S., Schneider, A. M., & Stieglitz, S. (2006). Eservices as pull strategies within public private partnerships-evidence from case studies. *University of Potsdam*.
- Lemstra, W., & Melody, W. H. (Eds.). (2014). *The Dynamics of Broadband Markets in Europe: realizing the 2020 digital agenda*. Cambridge: Cambridge University Press.
- Limbach, F., Kübel, H., & Zarnekow, R. (2014). *An Empirical Contingency Perspective on Cooperative Municipal Broadband Adoption*. Twentieth Americas Conference on Information Systems, Savannah.

- Massaro, M. (2017). Radio Spectrum Regulation in the European Union A three-level context. (Dissertation, Chalmers University).
- Moga, T. L. (2009). The contribution of the neofunctionalist and intergovernmentalist Theories to the evolution of the European integration process. *Journal of alternative perspectives in the social sciences*, 1(3), 796-807.
- Nucciarelli, A., Sadowski, B. M., & Ruhle, E. O. (2014). Should next generation access networks fall within the scope of universal service? A European union perspective. *Government Information Quarterly*, 31(1), 90-99.
- Rajabiun, R., & Middleton, C. (2015). Regulation, investment and efficiency in the transition to next generation broadband networks: Evidence from the European Union. *Telematics and Informatics*, 32(2), 230-244.
- Picot, A., & Wernick, C. (2007). The role of government in broadband access. *Telecommunications Policy*, 31(10-11), 660-674.
- Pollack, M. A. (2005). Theorizing the European Union: international organization, domestic polity, or experiment in new governance?. *Annu. Rev. Polit. Sci.*, 8, 357-398.
- Ramos, S., Arcos, M., & Armuña, C. (2009). The role of public administrations in developing electronic communications infrastructures in Spain. *Info*, 11(6), 69–81.
- Renda, A. (2010). Competition-regulation interface in telecommunications:What's left of the essential facility doctrine. *Telecommunications Policy*, 34, 23–35.
- Rosamond, B. (2000). *Theories of European Integration*. New York: Palgrave-Macmillan.
- Shortall, S. (2008). Are rural development programmes socially inclusive? Social inclusion, civic engagement, participation, and social capital: Exploring the differences. *Journal of Rural Studies*, 24(4), 450-457.
- Senn, M. (2005). Decentralisation of Economic Law—An Oxymoron?. *Journal of Corporate Law Studies*, 5(2), 427-464.
- Skerratt, S. (2010). Hot spots and not spots: addressing infrastructure and service provision through combined approaches in rural Scotland. *Sustainability*, 2(6), 1719-1741.
- Skerratt, S., & Steiner, A. (2013). Working with communities-of-place: complexities of empowerment. *Local Economy*, 28(3), 320-338.
- Tadayoni, R., & Sigurdsson, H. M. (2007). Development of alternative broadband infrastructures—Case studies from Denmark. *Telematics and Informatics*, 24(4), 331–347.
- Tookey, A., Whalley, J., & Howick, S. (2006). Broadband diffusion in remote and rural Scotland. *Telecommunications Policy*, 30(8-9), 481-495.
- Troulos, C., & Maglaris, V. (2011). Factors determining municipal broadband strategies across Europe. *Telecommunications Policy*, 35(9-10), 842-856.

Van Kranenburg, H. L., & Hagedoorn, J. (2008). Strategic focus of incumbents in the European telecommunications industry: The cases of BT, Deutsche Telekom and KPN. *Telecommunications Policy*, 32(2), 116–130.

Wagter, H. (2010). How Amsterdam was wired for open access fiber. *Ars Technica*. Retrieved from https://www.bcs.org/upload/pdf/how_amsterdam_was_fibred.pdf

Wood, L. E. (2008). Rural broadband: The provider matters. *Telecommunications Policy*, 32(5), 326–339.

APPENDIX 1

Description of the network architecture elements

The network architecture consists of the following elements:

- Access Points, ‘APs’ or hotspots

An access point consists of radio equipment, outdoor or indoor antennae, communication management software and ports for connecting a wired network. Such points are responsible for receiving via the radiofrequency waves (RF), the information from the various devices and for passing it on, as well as for serving as an interconnection point with the access network. It is important for all the network access points to permit roaming, which involves keeping the connection active for users when they pass from the cover area of one access point to another one. Other functions such as DHCP⁹, NAT¹⁰ or firewall properties, the Radius server, etc. can be taken on by one of the access points for the entire network, especially in the case of small networks, although these are more often taken on by the AP controller or by dedicated external equipment.

- User Terminals:

User terminals are generally items of equipment that have a wireless adapter that complies with Standard IEEE 802.11 and that enables a piece of equipment to be connected to the wireless network. Most devices and computers are now equipped with a wireless network adapter that has to be compatible with the standard(s) that support(s) the access point(s). This is usually the case, given that access points generally implement Standard IEEE 802.11n, and the most recent ones,

⁹ DHCP: Dynamic Host Configuration Protocol, is a server that has a list of dynamic IP addresses and is assigning them to clients as they become free, knowing who has been in possession of that IP, how long they have had it and to whom it has been assigned afterwards

¹⁰ NAT: Network Address Translation, it is a mechanism used by IP routers to exchange packets between two networks that mutually assign incompatible addresses. It consists of converting, in real time, the addresses used in the transported packages.

also implement Standard IEEE802.11ac. APs that support Standard 802.11n are compatible with the IEEE 802.11a/b/g/n devices, i.e., with those of the same standard and with all the old equipment. APs that implement Standard 802.11ac, are inherently compatible with IEEE 802.11a/ac devices, although in practice, they are also compatible with the rest of the standards, either because they also contain Standard IEEE 802.11n, or even because although equipment is manufactured that does not comply with Standard 802.11ac, it does give cover not only in 2.4 GHz but also in 5 GHz, and they are compatible with all the aforementioned standards.

- AP Controller

This is an item of equipment that makes it possible to centrally manage all the APs that constitute a WLAN network, providing the whole network with automated supervision and administration functions, especially if it is a network with a large number of APs or distributed APs. Apart from the router functionalities and roaming manager, it usually features other advanced user authentications (access profile definitions), traffic management mechanisms, Quality of Service (QoS) policies, DHCP server, security policy definition (firewall and Proxy server), automatic selection of the most suitable transmission channels for minimising internal and external interference, dynamic adjustment of the emission capacity of the different APs to improve cover/rate for the end user, etc. and other functions that are focused on this equipment, making it the only “smart” network element and dispensing with the need for further items of equipment in order to reduce costs.

- Load Balancer

This equipment makes it possible to distribute the different requests on a wired Local Area Network (LAN) via the different WAN connectivity ports provided by the ISP. It is particularly utilised on ADSL connection networks, because it helps to improve efficiency and reduce connectivity costs, preventing queues due to saturation and uneven load sharing between the various WAN connections.

- Repeaters/Wi-Fi Amplifiers or Network Extenders

These are all different terms for the same piece of equipment, a device that receives the signal from an AP node, amplifies it and retransmits it managing to increase the signal level in the zone, without a new AP having to be installed (which would otherwise increase the cost). Therefore, it is a solution suitable for zones with a low density of users, but with considerable cover, or with intermediate walls, as is generally the case in domestic environments. Indoors with a high density of users (classrooms, boardrooms, libraries, etc.), it is more advisable to use new APs instead of repeaters.

- Access Control, Firewall and other Equipment/Network Functions

There are other functions that can be taken on by other equipment, such as user validation and control via a RADIUS server, a server for virtual private networks (VPN), the firewall, etc., although currently the trend is for one single item of equipment to perform most of these functions, or even for some of these functions to be virtualised in a server connected to the cloud. These servers permit the user to dynamically adapt the resources to the number of users/access points our network has available, improving its scalability, and also help to considerably cut down on cost by allowing for the reuse of common management tools between different Local Authorities that have taken up the WiFi4EU initiative (e.g., user management via one RADIUS server that is shared by all the Spanish municipalities that take up this initiative).