What to do With the Wi-Fi Wild West

Horizon 2020
European Union Funding
for Research & Innovation

Deliverable	2.1
Title	Viability of business models for multi-operator Wi-Fi coordination platforms
Date	31/07/2015
Milestone	MS1
Editor	Koen Dittrich (TNO), Frank den Hartog (TNO)
Reviewers	Michael Mackay (LJMU), Faycal Bouhafs (LJMU), Qi Shi (LJMU), Jose Saldana (UniZar), Jorge Ortin (UniZar), Irfan Acar (AirTies), Ignacio Berberana (Telefonica I+D)
Approved by	General Assembly
Dissemination	Public

Abstract

This deliverable analyses current business models for Wi-Fi network operations, and the business models presumed by other Wi-Fi optimisation schemes as proposed in the literature. We compare the results with the business model assumed by Wi-5. Our approach is based on the premises that unlicensed spectrum is a “commons” in economic terms, everybody managing a Wi-Fi AP is a service provider, and under strictly defined circumstances, Wi-Fi traffic may be offloaded to 3G/4G networks. The Wi-5 solution thus builds on a prosumer business model and it creates a new entrance in the value chain for an over-the-top Wi-Fi added-value provider to solve the “tragedy of the commons”.

Wi-5 Consortium

Liverpool John Moores University	2 Rodney Street Egerton Court Liverpool, L3 5UK United Kingdom
Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	Anna van Buerenplein 1 2595 DA Den Haag Netherlands
Universidad de Zaragoza	Calle Pedro Cerbuna 12 Zaragoza 50009 Spain
Telefonica Investigación y Desarrollo SA	Ronda de la Comunicacion S/N Distrito C Edificio Oeste I Madrid 28050 Spain
AirTies Kablosuz İletişim San. ve Dış Tic. A.Ş.	Gülbahar Mah. Avni Dilligil Sok. No:5 Çelik İş Merkezi Mecidiyeköy Istanbul 34394 Turkey

Contents

Executive Summary

Spectrum is a scarce public resource whose usage is often strategic for the economy and society, and which must be optimised in view of the expected exponential growth in traffic and usages. Wi-Fi forms a special case as it uses unlicensed unmanaged spectrum. In this context, the Horizon 2020 Wi-5 (What to do With the Wi-Fi Wild West) project proposes an architecture based on an integrated and coordinated set of smart solutions able to efficiently reduce interference between neighbouring Wi-Fi Access Points (APs) and provide optimised connectivity for new and emerging services.

Business models for inter-domain coordination and hand-overs were never considered when Wi-Fi was originally developed. This deliverable describes the first steps in the development of a new business model to optimise the use of available unlicensed spectrum in urban areas, public spaces and offices. Our approach is based on the following premises:

- Unlicensed spectrum is a “commons” in economic terms.
- Everybody managing a Wi-Fi AP is a service provider.
- Under strictly defined circumstances, Wi-Fi traffic may be offloaded to 3G/4G networks.

We first assessed the existing Wi-Fi-related business models by analysing their level of inter-operator collaboration versus the amount of technical coordination functionality included in the service platforms involved. We further assessed the business models by applying the new DAMIAN (Digital Asset Mapping of Interdependencies in Actor Networks) methodology which supports the systematic description and analysis of competing value networks in the digital market based on the architectural control points and the actors who can leverage them. Our conclusions from that analysis include the following.

- Business models vary mostly in terms of who is fulfilling the role of network access provider and network service packager. This means that optimisation of spectral use will often be a matter of inter-provider interaction and coordination, which is inherently more difficult to achieve than intra-provider optimisation.
- None of the models enable the level of technical and organisational coordination that is needed to achieve the Wi-5 goals.

For the Wi-5 business model we therefore introduced a new actor: the spectrum usage broker or optimiser. The task of the spectrum usage broker is to optimise the spectrum usage of closely located Wi-Fi APs such that the Quality-of-Experience (QoE) is optimised over all users and fairly distributed among the individual users. The spectrum usage broker can achieve this by traffic steering (scheduling, redistributing traffic over Wi-Fi APs, Wi-Fi offloading to 3G/4G, etc.), but also by Wi-Fi radio resource management (channel allocation, transmit power optimisation, etc.). Fairness should be judged by an agreed policy or distribution algorithm.

A key question is how realistically such an actor can be initiated and maintained in a commercially viable way, especially when it is expected to broker spectrum between different operators and has to include Wi-Fi offloading to 3G/4G networks as a possibility. We therefore analysed in more detail the use case of Wi-Fi congestion in an apartment block where the tenants all arrange their broadband access independently and have different service providers available to choose from. We then conclude that this problem is a typical example of the “tragedy of the commons” and that a solution where tenants agree that their APs will be controlled by the caretaker’s Software-Defined Networking (SDN) controller is in agreement with the recommendations in the literature relating to the “tragedy of the commons”.

Abbreviations

3GPP	3rd Generation Partnership Project
ANDSF	Access Network Selection and Discovery Function
AP	Access Point
API	Application Programming Interface
BMI	Business Model Innovation
CDN	Content Delivery Network
CN	Community Network
CPE	Customer Premises Equipment
CS	Crowd Shared
DAMIAN	Digital Asset Mapping of Interdependencies in Actor Networks
DSL	Digital Subscriber Line
ED	End Devices
FRAND	Fair, Reasonable And Non-Discriminatory
HGI	Home Gateway Initiative
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPTV	IP TeleVision
ISP	Internet Service Provider
IT	Information Technology
MAC	Medium Access Control
MOBENA	Methodology Of Business Ecosystem Network Analysis
ONF	Open Networking Foundation
QoE	Quality of Experience
QoS	Quality of Service
RBV	Resource Based View
SDN	Software-Defined Networking
SI	Shared Infrastructure
SP	Service Provider
SSID	Service Set IDentifier
VNA	Value Network Analysis
Wi-5	What to do With the Wi-Fi Wild West
Wi-Fi	Wireless Fidelity
WISP	Wireless Internet Service Provider

1 Introduction

1.1 Wi-5 background

The last few years have witnessed a significant increase in the use of portable devices, especially smartphones and tablets thanks to their functionality, user-friendly interfaces and affordable price. For connecting to the Internet, most of these devices make use of IEEE 802.11 wireless technology, commonly known as Wi-Fi, in addition to 3G/4G, due to Wi-Fi's speed, maturity, efficiency, and attractive pricing.

Given this rising demand, Wi-Fi is facing mounting issues of spectrum efficiency due to its utilisation of non-licensed frequency bands, so improvements continue to be added to the standards in order to improve performance and adapt it to new demands. For example, as Wi-Fi saturation increases in areas such as business centres, malls, campuses or even whole European cities, interference between these competing APs can begin to negatively impact users' experiences. At the same time, real-time interactive services such as Voice over IP, video conferencing, and online games, have grown in popularity and are now used across a range of mobile devices. These share the same connection with "traditional" applications, such as e-mail and Web browsing, but are far more bandwidth-intensive and require consistent network capacity to meet user Quality of Experience (QoE) demands.

In this context, the Horizon 2020 Wi-5 (What to do With the Wi-Fi Wild West) project proposes an architecture based on an integrated and coordinated set of smart solutions able to efficiently reduce interference between neighbouring APs and provide optimised connectivity for new and emerging services. Cooperating mechanisms will be integrated into Wi-Fi equipment at different layers of the protocol stack with the aim of meeting a demanding set of goals:

- Support seamless hand-over to improve user experience with real-time interactive services.
- Develop new business models to optimise available Wi-Fi spectrum in urban areas, public spaces, and offices.
- Integrate novel smart functionalities into APs to address radio spectrum congestion and current usage inefficiency, thus increasing global throughput and achieving energy savings.

1.2 Scope and structure of this deliverable

This deliverable describes the first steps in the development of a new business model to optimise the use of available unlicensed spectrum in urban areas, public spaces and offices.

The rest of this deliverable is structured as follows. In section 2 we introduce our novel approach to dealing with Wi-Fi congestion, which is based on three premises: unlicensed spectrum should be treated as an economic "commons"; consumers managing a Wi-Fi AP should be seen as service providers; and Wi-Fi traffic may be offloaded to 3G/4G networks to save spectrum. In section 3, we discuss the theoretical background of business modelling and value networks, and present the DAMIAN methodology. In section 4, we discuss current business models for Wi-Fi capacity use and introduce the framework of a new Wi-5 business model. Section 5 concludes the deliverable.

1.3 Relationship with other deliverables

The material in this document relates to the following deliverables:

D2.3: This will include the collected use cases and the requirements. Use cases can only be realistic when they are based on viable business models. Requirements follow from the concerns of all stakeholders playing a role in the business models.

D2.4: The Wi-5 architecture description will depend on the requirements of all stakeholders, and consequently will depend on the chosen business model. This dependence is further explained in section 4.3.

D2.5: The final Wi-5 architecture will be presented together with the final business model, after the results of deliverable D2.1, D2.3 and D2.4 have been trialled and iterated with the industry.

2 Research objectives

2.1 Introduction

A universal wireless broadband service is considered of crucial importance for the socioeconomic development of Europe, as expressed in the 2020 Digital Agenda. In its Communication on “Promoting the shared use of radio spectrum resources in the internal market” [1], the Commission concluded that *spectrum is a scarce public resource whose usage is often strategic for the economy and society, which must be optimised in view of the expected exponential traffic and usages growth*. Different studies, e.g. [2], also show that scarcity of radio frequency spectrum is a limiting factor for the development of wireless broadband networks. To address this capacity issue, expansion of the radio spectrum and the development of radio technologies with improved spectral efficiency are being pursued.

Wi-Fi forms a special case as it uses unlicensed, unmanaged spectrum. The overwhelming success of tablets and smart phones is a key factor amongst others related to the current dense deployment of Wi-Fi APs in practically all homes with an Internet connection. The drawback of this dense deployment is the potential for co-channel interference of nearby APs as Wi-Fi has no mature radio resource management protocols to optimise the use of the frequency spectrum. Figure 2.1 shows a typical example of the 2.4 GHz unlicensed band being spectrally congested with Wi-Fi signals in a densely populated residential area.

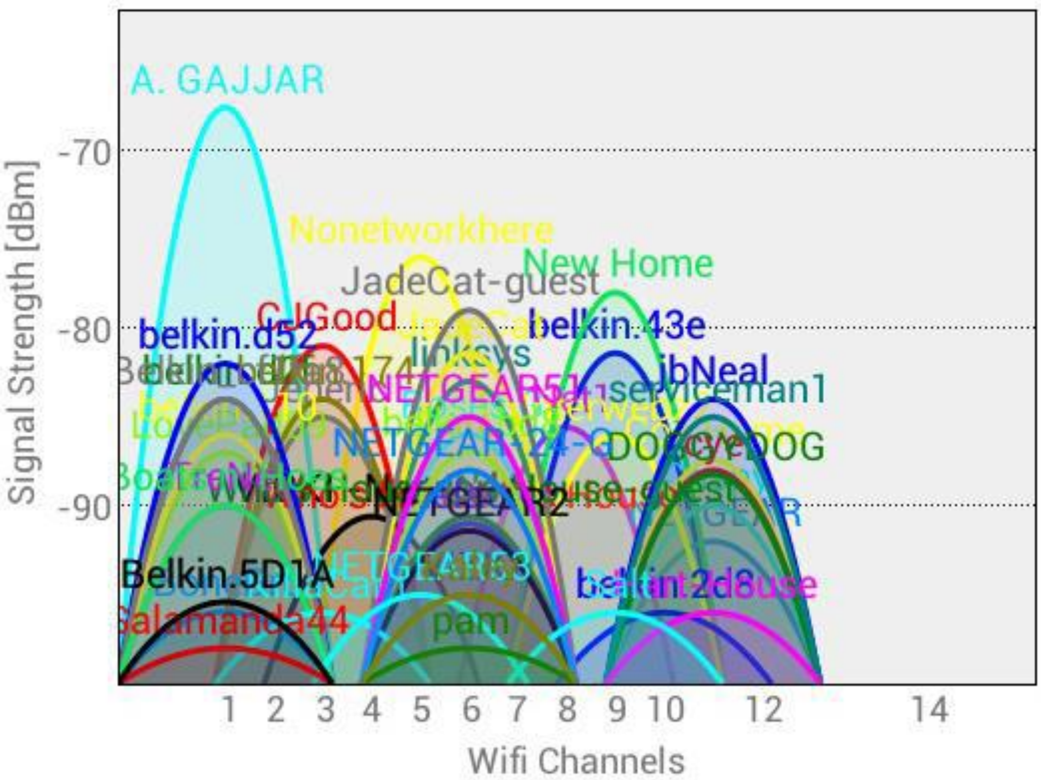


Figure 2.1 A typical example of the 2.4 GHz unlicensed band being spectrally congested with Wi-Fi signals in a densely populated residential area.

Spectrum efficiency improvement could also be achieved on higher communication layers than radio link resource management, e.g. by rerouting traffic to other (Wi-Fi or non-Wi-Fi) networks. However, mechanisms for the cooperation between different Wi-Fi APs and other networks to deliver seamless hand-over or roaming services do not yet exist, especially not for the case where the networks are owned and controlled by different providers, where the term "provider" could range from an individual (person) with a Wi-Fi-enabled modem right through to large enterprise organisations, or even service providers with a commercial Wi-Fi infrastructure. This is, however, a reality in many spectrally congested environments in Europe today, such as apartment blocks: interfering APs are generally owned and controlled by different entities.

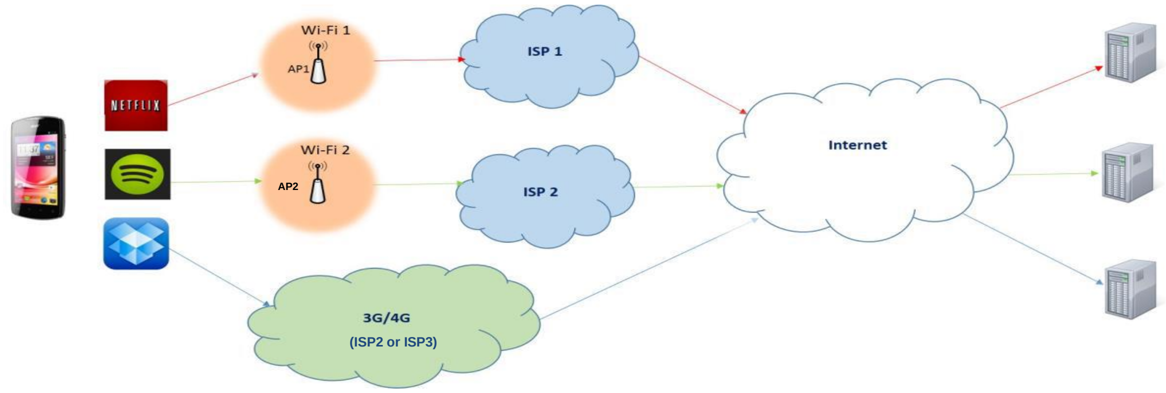
The main reason why the necessary cooperation and hand-over mechanisms do not yet exist is that the business models for inter-domain coordination and hand-overs were never considered when developing Wi-Fi in the first place. The current radio resource management protocols were developed for the case that an operator has the exclusive rights for a (licensed) frequency band, whereas in the case of Wi-Fi there is no exclusive use of the frequency spectrum by one (licensed) operator. Instead, every Wi-Fi AP is basically "on its own" in dealing with the polluted spectrum it finds itself in, and the solutions that the industry is currently developing are largely based on the assumption that the paradigm of the "lonely Wi-Fi AP" is not going to change: the Wi-Fi community develops intra-AP auto-configuration mechanisms, or at best coordinated configuration mechanisms for use within a single operator managed domain.

In this deliverable we present an alternative approach, which is based on the following premises:

- *Unlicensed spectrum is a "commons"*, as in the famous "tragedy of the commons" problem description, postulated by Hardin [3]; this means that the whole gamut of solutions being developed in the past for this abstract problem (regulation, pricing, brokering, etc.) can possibly be applied to Wi-Fi congestion in some way or another.
- *Everybody managing a Wi-Fi AP is a service provider* (or operator), including consumers who just buy a Wi-Fi AP in the store: an AP is not an end device on which a service is consumed, but a device offering Internet access to other end devices (which may or may not be owned by the same person as the one operating the AP) and using valuable spectrum for doing so. We adopt the term "prosumer" for a private person who is using wireless spectrum by means of his end devices but is also (capable of) offering a (network) service, namely wireless access, to other consumers.
- Under strictly defined circumstances, *Wi-Fi traffic may be offloaded to 3G/4G networks* in order to save unlicensed spectrum for the common good. Today, most literature assumes that 3G/4G networks have limited capacity and high usage costs compared to co-located Wi-Fi networks, which are assumed to be "free" and of unlimited capacity. In many cases, this assumption is not correct anymore. Many mobile operators have started to provide flat-fee subscription models, and due to the congestion as indicated in Figure 2.1, many consumers now often decide to stay on the 3G/4G network despite their smartphone desperately trying to automatically perform a hand-over to the Wi-Fi network. The Wi-5 business model thus has to take into account the option of being able to offload Wi-Fi traffic to a 3G/4G network if conditions such as pricing and available 3G/4G capacity are right. We acknowledge that the current tendency of operators is to do the opposite: try to offload as much as possible traffic from the 3G/4G network to the Wi-Fi network. As said before, this is not necessarily benefitting the QoE of the end-users anymore at a given pricing level, and the possibility of off-loading in the other direction should now be taken into account also.

Concluding, the Wi-5 solution will build on a prosumer business model and it will create a new entrance in the value chain for an over-the-top Wi-Fi added-value provider to solve the "tragedy of the commons". This combination of a prosumer network model and a lean Wi-Fi added-value provider has not been proposed before, and it may cause a shake-up of the existing market dominated by commercial network providers that have to recover large investments and satisfy investors, and non-commercial end-users who just fight for as much spectrum as possible by means of installing repeaters, illegal high-power APs, or other devices. We instead propose to mine the vast amount of existing Wi-Fi wireless capacity of the 145 million DSL, fibre or cable home gateways in Europe [4] in a more intelligent and coordinated way, resulting in an improved QoE for everybody, by sharing the spectrum in as fair a manner as possible.

Figure 2.2 shows a schematic view of a Wi-Fi network as under consideration in Wi-5. There are three operators, two operating potentially interfering Wi-Fi APs and one operating a 3G/4G network. Consumers have an end device running various different services and the Wi-5 network and business model should enable the device, for any given service, to attach to the network that offers it a fair QoE given its subscription model, and to configure the network parameters such that the total QoE perceived



by this consumer and those around it is optimal.

Figure 2.2 Schematic overview of a Wi-Fi network as under consideration in Wi-5.

2.2 Approach

In order to develop such an alternative business model, we have taken the following approach:

- We analysed current business models for Wi-Fi network operations.
- We analysed business models presumed by other Wi-Fi optimisation schemes as proposed in the literature.
- We compared existing business models with the Wi-5 business model as proposed in this deliverable.
- We checked our findings with various operators in the Wi-5 Operator Board[1] and in the Home Gateway Initiative (HGI, www.homegateway.org).

In the previous section we stated that the necessary cooperation mechanisms and the related business models for inter-domain coordination do not yet exist for Wi-Fi networks. As a first step in analysing current business models, we therefore plotted in a qualitative manner the level of technical coordination

[1] The Operator Board is an advisory gathering of interested parties, providing valuable guidance to the project in terms of exploitation of the envisaged tools and services and standardisation issues. The members of the Operator Board are companies that operate public or semi-public networks. They are invited to give feedback and/or direction during the project's life cycle in two regular meetings per year.

present in current platforms against the level of inter-domain cooperation between the actors involved in the business model related to these platforms. This results in a figure like shown in Figure 2.3, where the horizontal axis represents the amount of technical coordination that the Wi-Fi optimisation schemes under consideration require, and the vertical axis represents how much the Wi-Fi optimisation schemes enable inter-operator cooperation. The red dots are then the business model / technical platform combinations under consideration. As explained in the previous section, and indicated by Figure 2.2, maximum Wi-Fi spectrum optimization with a fair QoE for all users can be achieved by a platform that involves multiple operators and multiple technologies. In the framework of Figure 2.3, that would translate into a node in the upper-right quadrant. In Section 4 we will show that indeed none of the existing business model /technical platform combinations fulfils that requirement.

We further assess collaborative business models for Wi-Fi spectral use by applying a new methodology (DAMIAN, Digital Asset Mapping of Interdependencies in Actor Networks) which supports the systematic description and analysis of competing value networks in the digital market based on the architectural control points and the actors who can leverage them. By means of this methodology the complexity of digital value networks can be comprehended and the effect of (future) policies and regulations on the positions of power in the value network can be assessed.

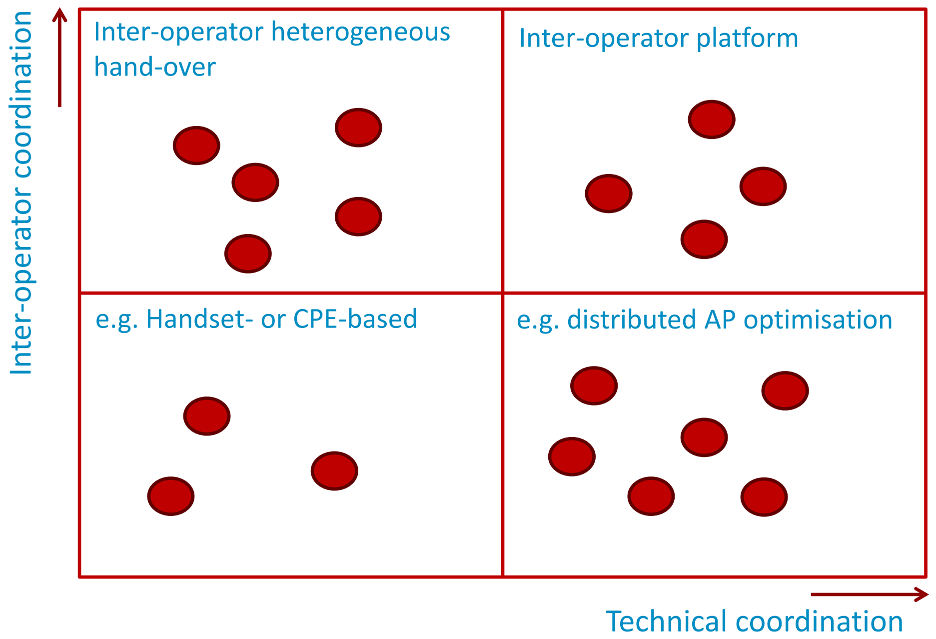


Figure 2.3 Overview of potential business models combining inter-operator and technical coordination.

3 Theoretical background

3.1 Business model innovation

It is commonly understood that business model innovation is in essence an organisational design process (e.g. [5], [6]). Some initial attempts have been undertaken to try to devise an understanding and a list of common business model design building blocks and themes (e.g. [7], [8], [9]) and business model archetypes (e.g. [10]). However, for firms confronted with different boundary conditions related to their environment (e.g. based on sector, industry, regulation and ecosystem characteristics) and their organisation (e.g. based on structure, culture and strategy), it is difficult to confidently design an appropriate business model based on the current knowledge.

To help firms in designing their business model, a relevant – though limited and often not large-scale empirically validated – set of tools is currently available. For example, there are important and well-known tools for visualising business models such as the Business Model Canvas [5], designing and benchmarking the focal firm's value model and value proposition such as the Value Curve model [11], mapping the focal firm's position in the surrounding value network such as the activity system and value chain analysis tools [12]. However, the current set of business model innovation tools lacks integration in an overarching process structure for business model innovation and a clear set of recommendations for when and how to use them, and what their key underlying assumptions are. Also, validated tools for important phases in the business model innovation process are missing, especially with respect to business model innovation diagnostics (Do I need business model innovation?), benchmarking (What is the relative performance of my business model?), and evaluation (How may this business model design idea perform given certain environmental and organisational characteristics?).

We take an organisational design approach for studying and applying Business Model Innovation (BMI, e.g. [13], [14]). In outlining the conceptual foundations of business model innovation, this deliverable develops a systematic exploration of the three aspects of business models: 1) value creation; 2) appropriation mechanisms; and 3) the architecture that defines and governs 1) & 2). Thereby, we conceptually clarify, delineate, and couple business model innovation with important concepts such as strategy, assets and capabilities. Instead of taking the perspective of a single firm, we incorporate ecosystems and open innovation thinking to adequately explore value creation and capture of the focal firm's business model innovation in relation with its partners in the value network and the overall value architecture. As such, the common language we will use to uniformly describe business models and their innovation will draw upon the organisational design approach (e.g. [13], [14]), open innovation perspective (e.g. [15], [16], [17]), ecosystem perspective [18], the activity system perspective [7] to business modelling, and contingency theory [19].

Many business modelling approaches start from a conceptual visualisation of the context of one offering on the market, typically of one firm [20]. The extended notion of a multi-firm interaction with several offerings and objectives is typically visualised by means of a value network [22]. Still, most approaches are aimed at visualising the interactions, often around one focal firm and looking at one final offering on the market. A more truthful representation of reality in a business model should be seen as a network or graph of actors, the activities they perform, and all kinds of interactions between these actors. Likewise, the open innovation perspective [22] suggests the need for several business actors to collaborate to realise a value proposition in a relationship of mutual benefit, which we discuss in section 3.2.

3.2 Value network analysis

The challenge at the root of every business venture is how to create and appropriate both tangible and intangible value. Traditionally, value creation is explained as a linear chain of activities that are being performed to deliver a product or service to the market [23]. This model is linked to the production line of the industrial era: firms buy materials from suppliers, transform these materials into products and then sell them on to consumers. Later, Stabell and Fjeldstad [24] extended this view with two alternative configurations of the value chain: the value network and value shop. How the created value is appropriated by the business actors along these value configurations is determined by the competitive forces in the market [25]: the less competitive rivalry, the more attractive a market. This does not imply that every enterprise in an attractive industry will be equally profitable. Based on capability logic [26], firms can achieve higher profits through the application of key resources and capabilities at the firm's disposal [27].

Today, intangibles represent the majority of value for many businesses [28] and the network is the main instrument for value conversion. The winners are no longer defined by the tangible value they accumulate along the value chain, but by the network externalities they can leverage within a web of actors across industries. This view implies that the environment is no longer beyond the influence of individual actors in business communities. Hence, organisations should effectively use their capacity to form strong social, professional and exchange relationships to relate their activities and assets to those of customers, suppliers, competitors and governing organisations within their business context [29]. This can only be achieved by understanding the interconnected business models of actors in a network and the forces that influence such networks.

Parties delivering a service to end-users are almost always dependent on the assets of other parties. They combine their own assets with those of others to build a service. Thus one party can deploy its assets for its own services or make them available for use by other parties (e.g. a Content Delivery Network, CDN). Sharing and using the assets of another company creates interdependencies between parties and their services, which affects their competitive position. Regulation affects the strength of the dependencies, e.g. net neutrality decreases the extent to which a network operator can control usage of the access network by competing services. In order to grasp the interdependencies between parties in an industry we need to consider its portfolios of assets, rather than a single asset, because it is via these assets that parties are related and make transactions.

In this view, the dynamics in an ecosystem thus revolve around assets. We define assets as a strategic ownership of a party that contributes to the value of a service for the end user. An asset can be both tangible (e.g. an access network, rights) and intangible (e.g. brand, user base) [30]. The markets for telecom, media and the Internet have become intertwined at multiple levels and the Internet, combined with a tremendous development in devices such as smartphones and smart TVs, has introduced many alternative distribution and business models for content and services. The traditional value chain (creation, aggregation, distribution and consumption) thus no longer adequately describes how assets are controlled and services delivered. The value chain has been transformed into a network structure, in which assets of different players are *used and shared* by one-another (co-opetition) [31]. It holds multiple technologically and organisationally alternative 'paths' for service delivery. Each player tries to maintain or expand its position in the network by creating value for end users, based on its own assets and selective use of other players' assets [30], [32].

An approach that takes on a specific network perspective is Value Network Analysis (VNA). VNA captures the activities in which a network of actors convert tangible and intangible assets into specific business, economic, or social good by transacting both tangible and intangible deliverables. VNA uses graphical network models to represent stakeholders within and across organisations and clarifies the relations between actors. Although VNA defines assets, it does not pose the asset as central to the analysis, but rather uses it to identify value transactions between actors.

Where and how value network actors can extract value from the network can be determined by control points: parts of the value network at which management can be applied through economic power [33], [34], [35]. This power can be defined based on both transaction cost theory [36], [37] and the resource based view [27], [38]. A more specific view on control points comes from Woodard [39], who proposes the concept of architectural control points, stemming from "*system component[s] whose decision rights confer architectural control over other components*" (p. 361). This concept may be specifically of interest for system industries, like the media, Internet and telecom industry, as controlling certain architectural features can profoundly influence the entire business community.

To define which points in the value network can be characterised as control points and evaluate the success of business models utilizing them, the Value Chain Dynamics Working Group at MIT [34] proposes interchangeability, demand, value and time as criteria for determining the strength of a control point. This approach is taken further in the "methodology of business ecosystem network analysis" (MOBENA) [40]. It is designed to systematically study the structure and fluxes of a business ecosystem and takes into account potential for strategic analysis and future perspective. It revolves around market (ecosystem) analysis, a network of companies and enabling technologies and defining future scenarios of impactful and uncertain drivers. Assets, control points and enabling technologies are also closely related to the resource-based view [27]. This approach tries to explain a firm's sustained competitive advantage by its internal sources. It states that if a firm is to achieve a sustained competitive advantage it must acquire and control valuable, rare, inimitable, and non-substitutable resources and capabilities, plus have the organisation in place that can absorb and apply them [41], [42], [43].

Kraaijenbrink *et al.* [44] analyse and provide some fundamental critique to the Resource Based View (RBV), namely insufficient acknowledgement of the importance of controlling assets, bundling resources and of the human involvement in assessing and creating value (capabilities). We argue that a view centred on assets is nevertheless relevant for our purpose as we do not seek to fully explain sustained competitive advantage, but the dynamics in the business ecosystem. And although the value of an asset is determined by its use, thus exogenously, the role of the (mainly technological) assets in our view is key to a company's presence in this ecosystem. These assets are tied semi-permanently to the company, so they give right to play and at the same time constrain its actions, because the building of assets costs time and represents investment, and as such implies path dependency.

VNA provides analytical indicators for value creation, structural dependency, stability, reciprocity and agility, based on the intangible and tangible transactions between actors. In our asset-centred approach we focus on the transactions between companies related to the assets *required for delivering the services*.

Where VNA focuses on the actual transactions to derive the indicators (rather than possible alternative transactions in which similar value could be attained), we focus on the qualities of the assets as a source for control on dependency and influence. This is approached by the availability of alternatives and the degree to which the asset is open for use by others (the construction of the categorisation and reciprocity is described at a later stage). Neither MOBENA nor RBV explicitly take convergence of technologies and competing regulations into account. A value network analysis of players in a digital ecosystem thus becomes extremely difficult when using methods like MOBENA or RBV, as different players, to which traditionally quite different regulations would apply, compete with each other in one converged market. In traditional methodologies the effects of these different regulations, which prevent establishing a level playing field for all parties, are not explicitly taken into account. However, since especially net neutrality and must-carry greatly influence the value of the network control point, as well as the assets controlled by the different competing players, a new methodology that structurally includes the effects of regulation is called for as we will discuss in the next section.

3.3 The DAMIAN methodology

Figure 3.1 presents the stages and steps in the Digital Asset Mapping of Interdependencies in Actor Networks (DAMIAN) method [45]. The main objective of this method is to create an impartial and shared foundation for discussions about policy and regulations in converging markets. This impartial and shared foundation is based on a systematic analysis and description of the service delivery flows in the Digital Ecosystem, consisting of 1) the activities that need to be performed in order to deliver a specific service to the intended end-users; 2) the actors who carry out these activities; 3) the strategic assets that the actors use and exchange to fulfil their activities in the value network; and 4) the rules and regulations that affect the positions and interactions in the value network. The outcomes of the DAMIAN-method are recorded in a so-called *service delivery canvas*. By means of this method and canvas, the many interdependencies between organisations in the value network can be unravelled, the complexity of the converging value network can be understood, and the effect of (new) policies and regulations can be evaluated. The DAMIAN method consists of four consecutive steps, which will be explained in more detail below.

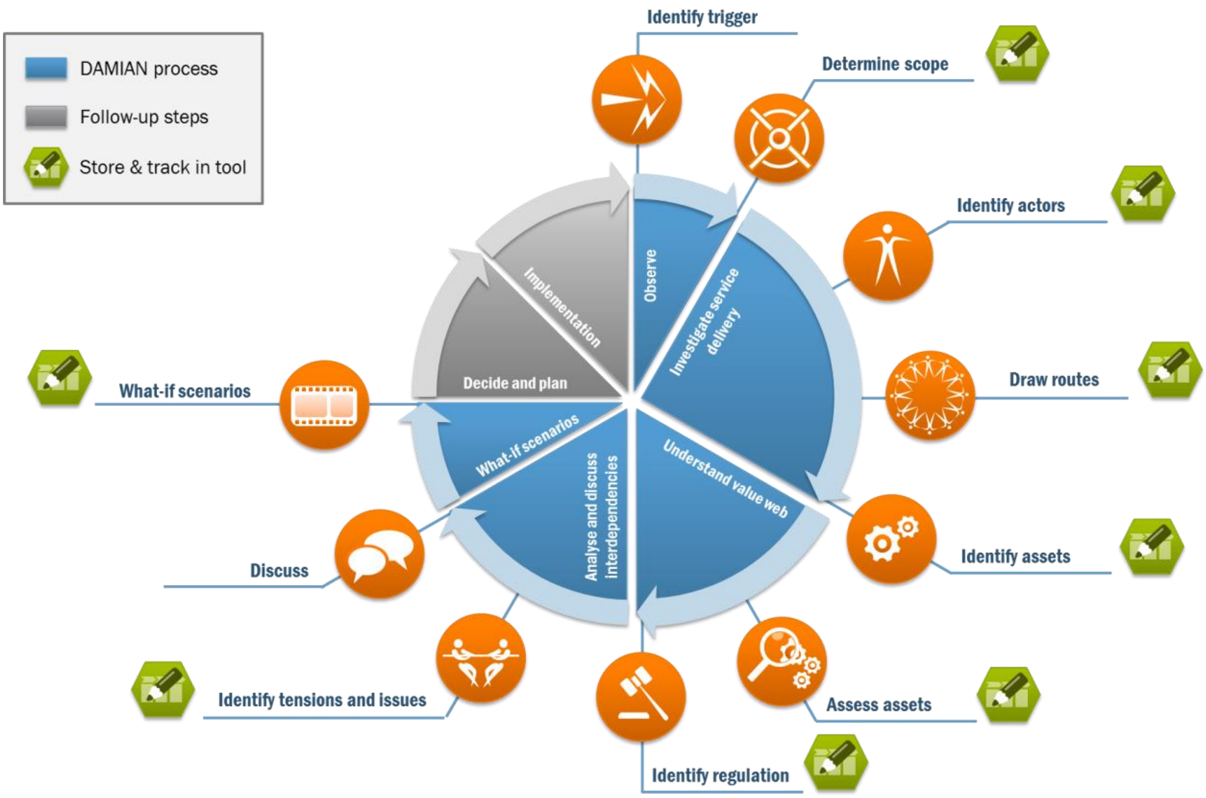


Figure 3.1 The DAMIAN methodology at a glance.

Stage 1. The starting point for applying the DAMIAN-method is a current and well-defined case, which causes (potential) tensions in the converging media-Internet-telecom market. Possible cases that can be analysed by means of the DAMIAN-method are, amongst others:

- The emergence of new service delivery flows because suppliers expand their activities in the value network (e.g. cable providers experience competition for their television services from the live and video-on-demand services of media companies).
- New entrants that offer similar services as incumbent parties in the ecosystem, but under different commercial and regulatory conditions (e.g. Internet actor Netflix competes with the television services of cable providers and broadcasters, but is not regulated by the same rules that apply to traditional media actors).
- The growing importance of certain strategic assets, which influences the power positions in the value network (e.g. as personal content recommendations become more important, so do data about the viewer and his/her viewing habits become more important assets).

After defining the case, it is important to determine the scope for the analysis. The scope consists of a set of end-user services and their distribution models that are related to the case and are found important by the involved stakeholders, described by the name of the service and the actor that offers it. It is important not to include too few or too many relevant services in the analysis here as including too few services might result in a very narrow focus on issues that at the moment of doing the analysis get a lot of (media) attention. However, including too many services in the scope results in a very extensive analysis. An optimal number would typically be 4-5 services provided.

Stage 2. The second stage in the DAMIAN-method is aimed at clarifying the way in which services are being delivered to the end-user:

- Which actors are involved?
- Which functional relationships exist between these actors?
- Which assets do the involved actors use and exchange to deliver the service?

The results of this stage are captured in the *service delivery canvas*. This canvas depicts the main activities that are often, but not always, executed to deliver services to the end-user. To create an overview of the service delivery routes, first the actors and relationships between them are recorded in the canvas. Then the method zooms in on the capabilities of the specific actors partaking in the value network by analysing which tangible and intangible strategic assets (e.g. distribution networks, content, brand, customers, etc.) they control and therefore can leverage to capture value in the service delivery route. A firm gains influence in the value network when its assets are scarce and in high demand by other business actors in the network. Conversely, firms that are mainly using other firms' assets to deliver their service to the end-user occupy a more dependent position in the value network.

Stage 3. To create an understanding of the power dynamics in the value networks of the Digital Ecosystem, the DAMIAN-method systematically analyses the interdependencies between actors in the value system by means of their strategic assets and the rules and regulations that apply to these assets. Assets determine where and how actors can capture value, such as making revenues, from the network and can assert influence. In other words, assets provide companies with *control points*: parts of the value network at which management can be applied through economic power [33], [34], [35]. The power an actor can leverage through the asset can be defined based on both the *competitive advantage* of the asset [27], [38] and how much it costs other actors to obtain the same type of asset [36], [37]. Regulation affects the ways in which actors can control their own assets to assert influence and can rely on other actors' assets, in order to prevent misuse of power between actors in the market and champion the common interest.

In the previous steps of the method we have already identified the assets that are important, and thus are assumed to bring a *competitive advantage*, in the delivery of the service. At this stage of the DAMIAN-method we zoom in on these assets to identify which points in the value network can be characterised as control points by assessing the identified assets in the service delivery on two scales (Figure 3.2): 1) How open is the asset for other actors to use?; and 2) How many alternatives are there for this asset?

In order to determine an asset as a source for control on dependency and influence between different parties in the value network, we plot the assets in the following two-dimensional space of openness (accessibility) and availability of alternatives as presented in Figure 3.2.

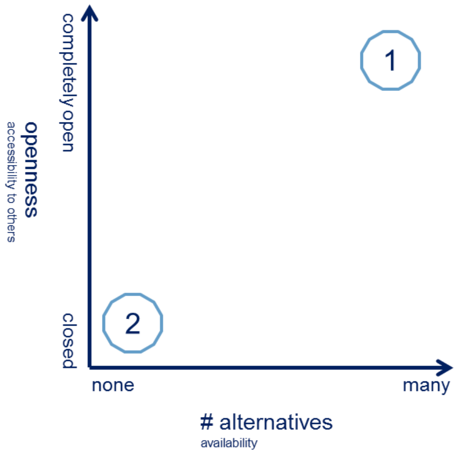


Figure 3.2 Dependency/Influence categorisation space.

As shown in the plot, asset 1 is accessible to all actors and there are many alternatives available. Therefore, one could say that the providers of services using this asset are hardly dependent on the owner of the asset and conversely that the owner is not in a position to influence the provisioning of services by others. Asset 2, on the other hand, is not accessible to others and no alternatives can be attained, so the asset is completely unique. This implies that any service for which this asset is required can only be delivered by the company controlling this asset. This does not *per se* mean that owners of assets in the lower left corner dominate the ecosystem, as they may themselves depend on assets of others as well. So Reciprocity, the mutual dependency, can offset strong influence.

Below we introduce the discrete levels of openness and availability and construct a classification of Dependency and Influence.

The distinguished levels of commercial openness are:

- **Open:** accessible to all at no (little) cost.
- **Fair use:** almost for free (up to a limit of usage).
- **FRAND** (Fair, Reasonable, And Non-Discriminatory): open licensed, term of use equal to all.
- **Commercial/exclusive:** terms of use are negotiated bilaterally and differ per party.
- **Closed**: asset is not accessible to others (but under debate and in demand).

As for the availability of alternatives we distinguish three aspects:

- The number of available alternatives (many, i.e. more than 3 or few).
- The switching (or installation) cost in case of alternatives.
- Entry barriers: if no alternatives are available, whether the asset can be easily built or not (entry barrier is either low or high).

In order to simplify the approach, we introduce discrete levels of openness and availability of alternatives and combine these into seven levels of influence and dependency (see Figure 3.23). On the left we see from bottom to top increasing levels of influence of an asset if it is used in a service of another party. On the right we see increasing levels of dependency if the asset used is controlled by another party. The seventh level (not depicted) is reserved for assets that are identified and are for own use only and no debate or demand is known, so it is not relevant for the Reciprocity. In this categorisation, the properties can be recognized that Barney [41] requires to have for sustainable competitive advantage in the Resource Based View. These properties are: resources should be rare, inimitable and non-substitutable. It also has similarities with the interchangeability criterion proposed by [34].

Figure 3.3 Asset influence and dependency based on degree of openness and number of alternatives[2].

Stage 4. By following the preceding steps in the DAMIAN-method, a complete overview has been created of the service delivery routes, including the most important assets, their openness for other actors, the range of available alternatives and the applicable policies and regulations. In this stage of the DAMIAN-method we will use this overview to identify and discuss (potential) tensions in the value networks by applying several filters, such as the openness of the asset, the number of alternatives available, specific policies and regulations, specific services, or disagreements on the openness/alternatives scores between participants in a multi-stakeholder workshop setting.

In the next section, we use the DAMIAN methodology (stages 1 and 2) to discuss current Wi-Fi business models. The reason for the use of only stages 1 and 2 will be explained in section 4.2.

[2] Note that the assessment of the asset is always done from the perspective of the service provider.

4 Review of current Wi-Fi business models

4.1 Distinction of business models

When reviewing current business models for Wi-Fi capacity use, we distinguish four main categories of business model: Community Networks, Wireless Internet Service Providers, Shared Infrastructure models and CrowdShared approaches (see [4] for a detailed explanation of these business models, which are presented as *alternatives* to traditional ones). In addition, we propose Software Defined Networks (SDN) -based solutions as an option for a coordinated business model for Wi-Fi capacity. Each of these business models is briefly explained in Table 4.1.

Table 4.1 Current Wi-Fi Business Models (based on [4]).

Community Networks (CNs)
- de-central/open
- network can serve for providing services and applications
Wireless Internet Service Providers (WISPs)
- commercially operated wireless Internet networks
- most common in areas with no incumbent telco or ISP
- often use wireless point-to-point or point-to-multipoint
Shared Infrastructure model (SI)
- owned by individuals or communities, and leased out to network operators
CrowdShared approaches (CS)
- set of nodes whose owners share common interests
- the home router creates two wireless networks, one private and one public
- A VPN is created for delivering public traffic
Wi-5 proposal: SDN-based solutions (SDN)
- Wireless network is dynamically programmable by network operator to provide any of the above services or others as wholesale to 3rd-party operators

The most common business models for Community Networks are Public Wi-Fi and Hotspots [46], mostly provided by a private access provider. Examples of Wireless Internet Service Providers (WISPs) are Cloud-Based Radio Access Networks [47], like Airjaldi in India [4]. In the Shared Infrastructure model the access network is owned by individuals but leased out to a network operator who typically uses them as a low cost medium to reach a population that is not served by other access services, e.g. in rural areas [4]. This kind of network has been studied and tested in the FP7 *Tucan3G* Project (http://www.ict-tucan3g.eu/), where an existing wireless infrastructure is leased to an operator to deploy

3G femtocells in remote villages in Peru. A well-known example for CrowdShared approaches is the services offered by the company Fon, which provides one public/shared access network next to a private one [4]. SDN-based solutions are relatively new and are somewhat atypical compared to the other Wi-Fi business models, in the sense that they can provide all the services listed in Table 4.1 [48]. Examples of SDN-based solutions are Odin [49], [50], Aeroflux [49] and Crowd [51].

In addition to the business models presented in Table 4.1, the use of ANDSF (Access Network Selection and Discovery Function, [52]) can be considered as an interesting business model for Wi-5 (see Figure 4.1 for a schematic overview of ANDSF). ANDSF is being developed by 3GPP, and assumes that a single operator can operate a mobile network as well as a Wi-Fi hotspot network. ANDSF then enables the operator to offload a dual-access network-enabled end device from the 4G network to the Wi-Fi network.

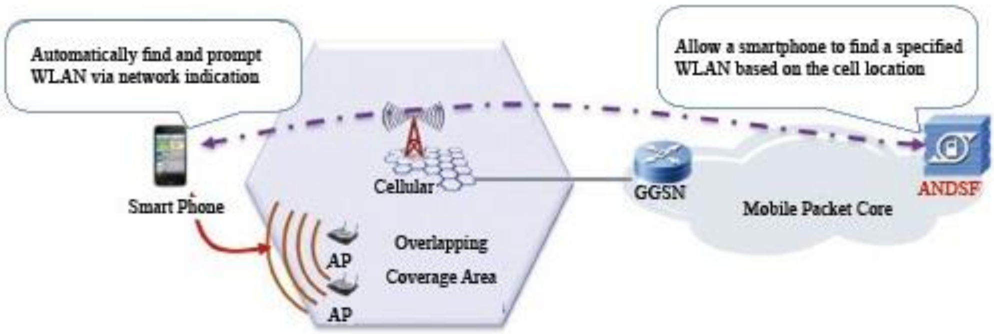


Figure 4.1 Schematic overview of ANDSF business model [53].

Another business model is based on the functionalities provided by the IEEE 802.11h standard [54] and that are also included in the 802.11n and 802.11ac standards. The 802.11h protocol contains the following elements:

- Dynamic Frequency Selection in the 5 GHz band to avoid interference with radar and satellite.
- Transmit Power Control reduces power transmitted by AP and end devices (EDs) to a bare minimum.

Although initially intended to avoid interference with Radar systems, these functionalities can be used to decrease the interference between different APs sharing the same channel. Strictly speaking, the APs are not really coordinating with each other by using 802.11h. They just try to avoid each other by utilising the spectrum that is free, as efficiently as possible. Also, current implementations, embedded in most state-of-the-art APs adjust frequency and power only very slowly (in the order of a few times per hour) and are not using these features for inter-AP coordination.

4.2 DAMIAN assisted analysis of current business models

In this deliverable we only applied steps 1 and 2 of the DAMIAN-method as described in section 3.3. The scope of the work, especially the premises set out in section 2.1, and the proposal to introduce a new type of actor in the SDN-enabled business model, created much discussion with the industry partners in the project, the Wi-5 Operator Board and the HGI [55]. This may be interpreted as a sign of the market disruptiveness of the new paradigm that we are introducing. Rough consensus exists in the industry about the viability of our model in a single-operator domain, but for inter-domain operation more proof of business model viability appears to be needed. For that, we have to evaluate steps 3 and 4 of DAMIAN also, but step 3 includes a detailed analysis of the assets of the new actor. The most important asset is arguably the coordination platform, but that is still under construction in the project. We therefore decided to have this deliverable largely dedicated to the outcome of these steps 1 and 2, leaving the elaboration of steps 3 and 4 for future work. We expect that after the trials with the new platform have been conducted, consensus will be reached on the scope of the SDN-based business model. We will present that model together with the final architecture in deliverable D2.5.

Step 1.

The *trigger* of this work is largely described in Section 2: there is a need to efficiently reduce interference between neighbouring Wi-Fi Access Points (APs) and provide optimised connectivity for new and emerging services.

The *scope* of the business model covers the services wireless Internet access and wireless access to managed services. For currently existing Wi-Fi-access business models, the main distribution models are described in Section 4.1. However, we do not limit the scope to Wi-Fi access only. Under strictly defined conditions, Wi-Fi traffic may be offloaded to 3G/4G networks. These conditions are that the mobile operator under consideration provides a flat-fee subscription model, and that 3G/4G resources are so abundantly available that offloading to the 3G/4G network has a negligible effect on the QoE of other users on the 3G/4G network. Other services provided by the 3G/4G network are out of scope of this deliverable.

Step 2.

In Table 4.2 we list all relevant *actors and their assets* for the main distribution models as shown in Table 4.1. It is important to realise that an actor (or business role) is defined as a party <u>or business unit within a party</u> which is able to perform a minimum set of related activities in a commercially viable manner. Larger companies often contain several actors. For instance, many incumbent telecommunication providers operate a network but also provide services. A consumer fulfils the role of end user, but can also act as a Wi-Fi access network provider to other consumers.

Table 4.2 Wi-Fi actors and their assets.

Actor	Assets	Examples
Access network provider	Manageable wireless AP, unlicensed spectrum, or licensed spectrum in case of the 3G/4G provider. Access network providers may or may not have knowledge of how to operate a network.	Commercial operators such as KPN in The Netherlands, or a community operator like Wireless Leiden (www.wirelessleiden.nl), office IT department or a prosumer.
Core network providers	Backhaul of the wireless access network. This may be a fixed network but can also be a wireless network in its own right. Core network providers have knowledge of how to operate a network.	Typically commercial operators, community operators and office IT departments.
Internet Service Provider	IP addresses, servers, edge routers, etc.	ISPs and some larger office IT departments

Network Service Packager	Consumer contact, network service packaging and operating knowledge, authentication and billing servers, etc.	Fon (https://corp.fon.com/) and Fon-like services, some hotel Wi-Fi services, etc. In [4] this role is called *Virtual Network Operator*.
Managed service provider	Content servers, QoS management tools, consumer contact, service operating knowledge, etc.	Basically any service provider can be a managed service provider if it has access to a network-operator's QoS management tools. Typically IPTV and telephony services.
Unmanaged service provider	Content servers, QoS management tools, consumer contact, service operating knowledge, etc.	Any over-the-top acting service provider such as Google or Netflix.
End Device manufacturer	Device functionality.	Samsung, Apple, Philips, Nest, Canon, Withings, etc.
End user	User feedback.	Residential dwellers, office workers, shopping people, etc.

When we plot these roles on the different activities of the Wi-Fi business model using DAMIAN, we get an overview of current coordinated business models as presented in Figure 4.2. Note that the names of the different parties are used here for illustration purposes and can be exchanged with other parties fulfilling similar roles. Figure 4.2 is close to what is described as a *service delivery canvas* in section 3.3 in the sense that the exact (wholesale) service delivery *relations* and compensation streams are not drafted in detail: for simplicity we have plotted the value web as a single-dimension value chain.

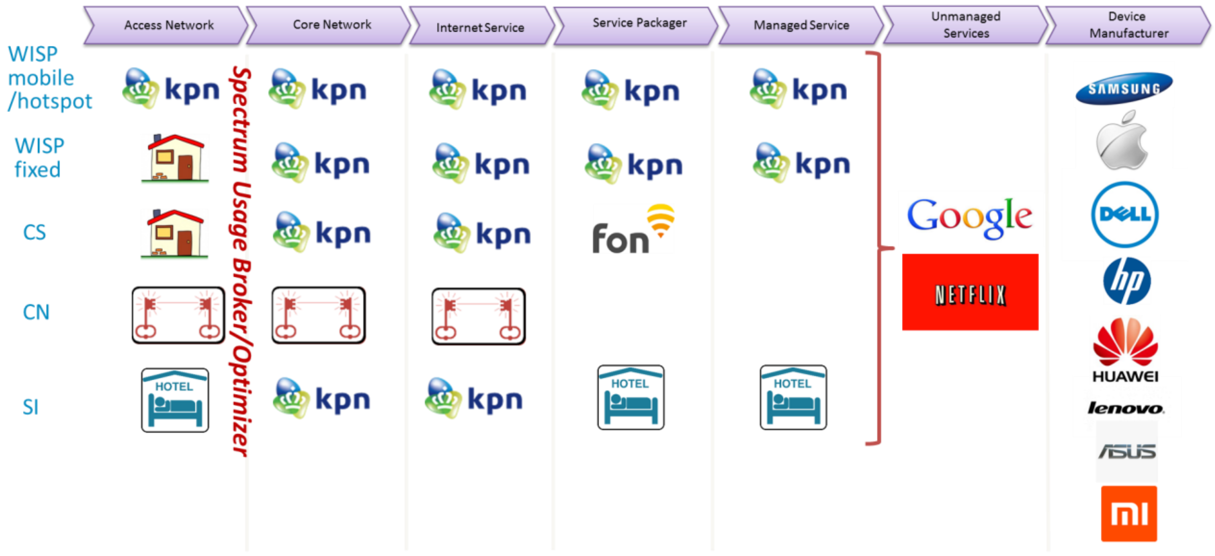


Figure 4.2 Current Wi-Fi business model with roles and activities. The "Spectrum Usage Broker / Optimizer" does not yet exist, and is an extra role to be introduced in Section 4.3 with the new Wi-5 "SDN" business model.

The meaning of most of the symbols used in the figure should be obvious. The house represents a residential prosumer. The symbol with the red keys represents a community network operator. In the case of Wireless Leiden, the community network operator is also operating the backhaul network, but that may be different for other community network operators. The unmanaged service providers and end-device manufacturers are the same for every business model. The abbreviated names for the various business models coincide with the more extended descriptions in Table 4.1. ANDSF and 802.11h are not depicted here for clarity: they have the same type of business model as WISP. The "spectrum usage broker" role will be explained in the next section.

The following conclusions can therefore be drafted from Figure 4.2:

- Business models vary mostly in terms of who is fulfilling the role of network access provider and network service packager. The role of network access provider can be taken by the core network provider or the owner of the local premises. This means that optimisation of spectral use will often be a matter of inter-provider interaction and coordination, which is inherently more difficult to achieve than intra-provider optimisation.
- In our examples, the core network and ISP provider roles appear to be taken by the same party in every business model. This triggers the question of whether one of these roles is relevant for our analysis. After discussion with the operators in the Wi-5 Operator Board, it was concluded that the role of core network provider is superfluous. It does not have any impact on the Wi-Fi optimisation issue, whereas the ISP has routing and switching assets that could be useful within the scope of the project.
- The Wi-5 "SDN" business model introduces a new actor, which we call "Spectrum Usage Broker / Optimizer"

In Figure 4.3 we plot the various business models against the level of technical and organisational coordination that is incorporated. It can be concluded that most models do not incorporate any form of coordination, neither technical nor organisational. ANDSF demands a relatively high level of technical integration, but is assumed to be handled within a single operator-managed domain.

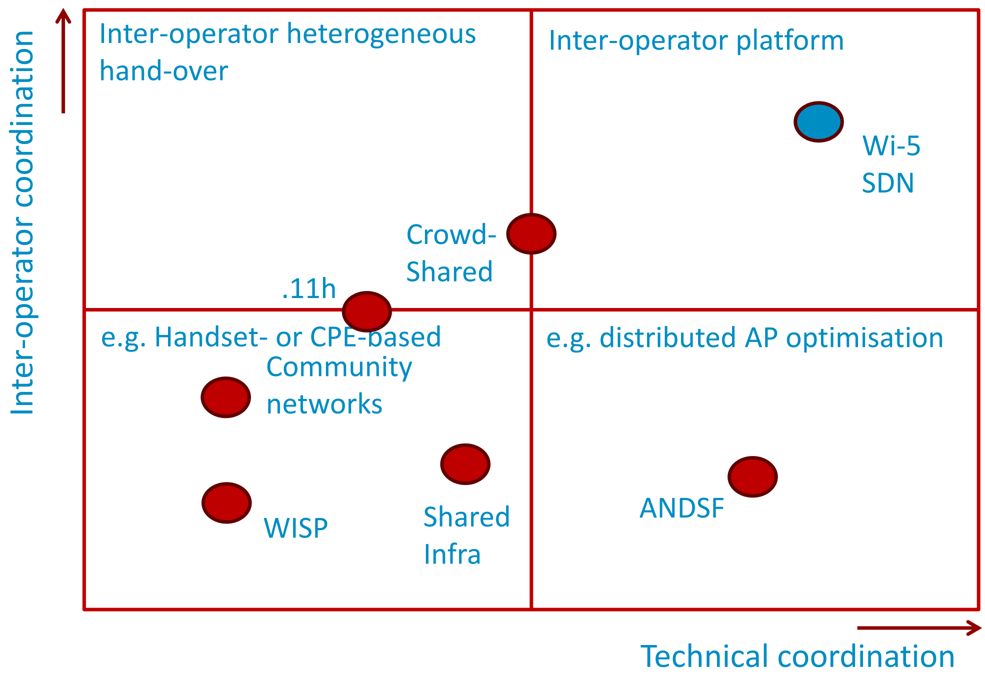


Figure 4.3 Overview of current Wi-Fi business models (red dots) in terms of their inter-operator and technical coordination. The proposed Wi-5 SDN business model is reflected with a blue dot and is described in Section 4.3.

802.11h enables Wi-Fi APs to take a relatively high level of consideration for their spectral environment, which is a basic requirement for enabling inter-operator coordination, but the actual coordination function is not present. Also, there is no guarantee that an 802.11h-enabled AP will receive the share of the spectrum it is entitled to given the needs of its consumers and the consumers of interfering APs. The CrowdShared model has a relatively high level of inter-operator coordination: the APs of the residential owners are coordinated by the Fon-like operator.

None of the models, however, enable the level of technical and organisational coordination that is needed to achieve the Wi-5 goals. For the Wi-5 SDN assisted business model we therefore need to introduce a new actor: the spectrum usage broker or optimiser. This role is detailed in the next section.

4.3 The spectrum usage broker

To determine the need for inter-operator coordination and thus a novel business model, one should first study the need for technical coordination between operator platforms given the goals that Wi-5 aims to achieve. Said otherwise, one should first investigate the Wi-5 architecture. However, the Wi-5 architecture is still under development and will be published later in deliverable D2.4. Since the architecture is dependent on the needs (business requirements) of the stakeholders and thus of the business model chosen, we have chosen to work on the business model first. To illustrate the need for inter-operator coordination we will therefore use the draft Wi-5 architecture that guided the start of the project, as presented in the project proposal. This draft architecture is presented in Figure 4.4.

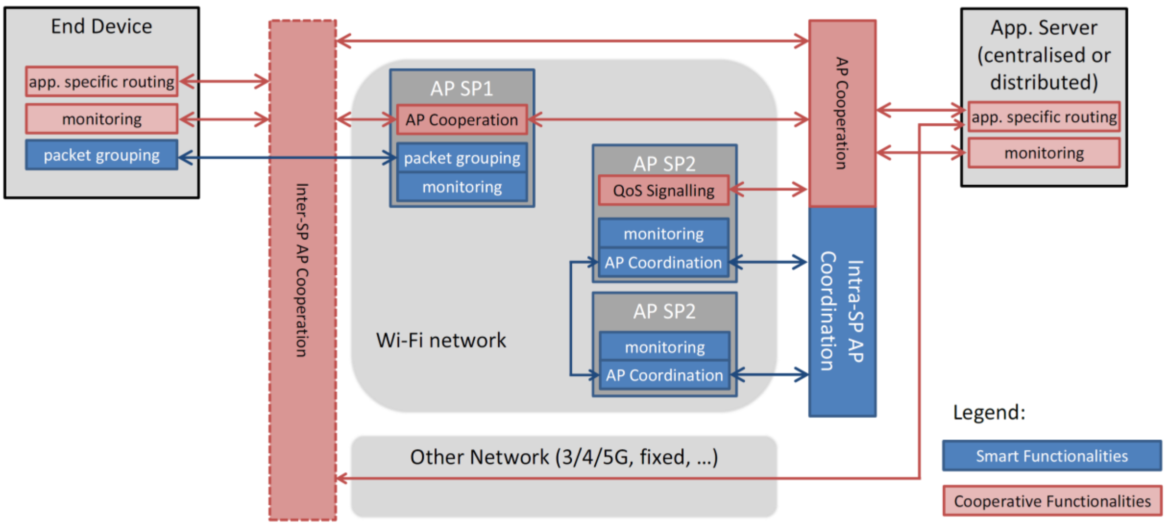


Figure 4.4 Draft Wi-5 high-level architecture.

The draft architecture is based on an integrated set of functionalities that will provide an improvement in Wi-Fi spectrum usage. In blue *(Smart Functionalities)*, we depict functionality for Wi-Fi APs which may or may not belong to the same network operator (here called Service Provider, SP). Two new functions are considered: intelligent packet grouping will group small 802.11n frames to save spectrum, but at the same time considering delay requirements from the service. AP Coordination is expected to dynamically auto-configure Wi-Fi APs located nearby regarding their channel, transmit power, etc., in order to achieve an optimal QoE for all users. This functionality may work intra- or inter-operator, in a fully distributed way or via a centralised AP Coordination platform. Second, we propose a set of functionalities in red *(Cooperative Functionalities)*, that will allow the user to join a mobile network, not only according to signal strength, but by also taking into consideration application specific parameters and quality metrics. The technical coordination functions described above translate into inter-operator organisational coordination as follows:

- Packet grouping needs collaboration between AP vendors and End-Device vendors. Collaboration will probably not go much further than joint standardisation efforts of this functionality. No inter-operator collaborative business model is needed.
- Fully distributed over-the-top heterogeneous cross-layer routing needs a flat-fee subscription model for the End Device on either network. Furthermore, it may need a function (centralised or distributed, not depicted in Figure 4.4) to protect the 3G/4G network from excessive Wi-Fi offloading. For this a collaborative business model is needed.
- Centralised AP coordination needs an independent coordination platform operator.
- Fully distributed AP coordination needs standardisation between AP vendors, but also a business model or technology that rewards operating a coordinating AP.

For implementing the technical coordination functionality, the project team is studying the use of Software-Defined Networking (SDN) techniques as pioneered by Schulz-Zander in 2014 [49]. Schulz-Zander's architecture is shown in Figure 4.5. SDN is a relatively new technology but is already seeing massive uptake, particularly among Cloud Computing operators. In essence, it centralises the control of routing and MAC address tables in routers and switches (traditionally performed locally or distributed) by using a controller which enables the programming of so-called flow tables in SDN-enabled switches using a protocol such as OpenFlow [56]. This architecture enables applications to have a network configured as needed and on demand. Schulz-Zander *et al.* extended the standard SDN architecture with Wi-Fi-specific programmable control features such as SSID configuration. For this they developed an additional protocol called *Odin*.

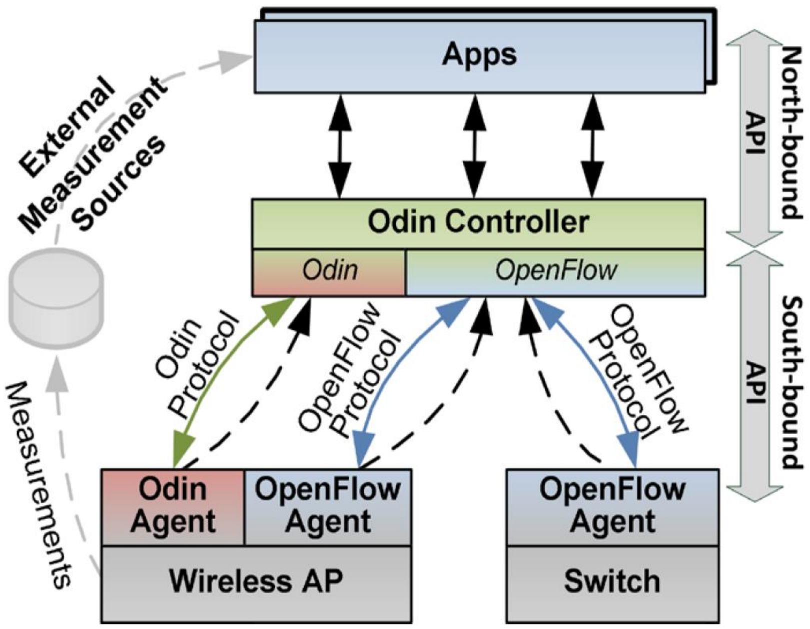


Figure 4.5 SDN-enabled Wi-Fi AP control [49].

Wi-5 is investigating whether Odin can be extended further such that the Wi-Fi spectrum use can be optimised, partly by traffic steering (standard OpenFlow functionality), but also by Wi-Fi radio resource management. Said otherwise, can an extended Odin controller be used for the centralised coordination functionality as discussed in Figure 4.4? If yes, who will be operating the controller? An architecture as shown in Figure 4.5 inherently assumes that the controller is operated by the same actor who is operating (i.e. is in control of) the switches and Wi-Fi APs under consideration. However, in the case of heterogeneous networks spanning different operator domains, the controller must be in the hands of an independent actor, which we call the *spectrum usage broker*. The task of the spectrum usage broker is to optimise the spectrum usage of Wi-Fi APs located nearby such that the QoE is optimised over all users and fairly distributed among individuals. The spectrum usage broker can achieve this by traffic steering (scheduling, redistributing traffic over Wi-Fi APs, Wi-Fi offloading to 3G/4G, etc.), but also by Wi-Fi radio resource management (channel allocation, transmit power optimisation, etc.). Fairness should be judged using an agreed policy or distribution algorithm. Ideally it should also have some control over Wi-Fi traffic not passing the APs, e.g. Wi-Fi Direct.

When discussing these ideas with the Wi-5 Operator Board and the HGI operator community, much time was spent on how realistically such an actor can be initiated and maintained in a commercially viable way, especially when it has to broker spectrum between different operators and has to include Wi-Fi offloading to 3G/4G networks as a possibility. Maybe the best use case to discuss this issue is the case of an apartment block where the tenants all arrange their broadband access independently, and have different service providers available to choose from, e.g. cable providers, telecom operators (fibre or copper line) and mobile operators. However, their Wi-Fi APs (some provided by the operators, others bought in a shop) interfere with each other, leading to sub-optimal spectral use overall. Some tenants try to solve this by buying extra strong APs and a lot of repeaters. The result may be satisfying for them in the short term, but ruin QoE for other tenants, who may react by installing many repeaters also. The end result is disastrous for everybody. This is a classic example of the “tragedy of the commons” [3] and much literature is available presenting solutions for this basically economic problem. In the case of an apartment block, the solution is fairly straightforward though, as an apartment has many other “commons” available to the tenants (hallway, joint garden, parking lot, etc.). Spectrum can be dealt with as just another commons: tenants make mutual agreements about its use, and a caretaker has to execute or enforce the agreements. In the case of spectrum management, tenants agree that their APs will be controlled by the caretaker’s SDN controller (which can be implemented by a firmware upgrade of the Wi-Fi AP) and that all will obtain a fair share of the spectrum. Either by rewarding or determent, the tenants should be encouraged to collaborate and not to install a rogue AP. Inter-apartment block interference will not be solved by this model, but we assume that intra-apartment block interference is the main culprit of Wi-Fi congestion. Depending on the intelligence of the controller, offloading traffic to the 3G/4G network may also be included and could especially be an option for tenants who have relatively good 3G/4G indoor coverage and also suffer from relatively strong intra-apartment Wi-Fi interference.

It is important to realise that, in the scope of this deliverable, the spectrum usage broker is a business role (actor) rather than a particular technical platform. If, for instance, an SDN controller is only controlling network elements (APs, 3G/4G base stations, etc.) within the domain of a single operator, the spectrum usage broker is an intra-company actor, not “visible” as such to the outside world. But how should inter-operator interference then be mitigated? The architecture that the Open Networking Foundation (ONF, www.opennetworking.org, the industry body standardising OpenFlow) is proposing for these cases contains some kind of super-controller: a controller of the controllers, which ONF calls an “orchestrator” [57]. The question then again arises as to who runs the super-controller, and indeed our assertion of a spectrum usage broker business role then still applies.

Slightly more complicated is the theoretical case where individual controllers do not answer to a super-controller but negotiate each other’s configuration via some peer-to-peer architecture and protocol. We have not seen such architectures in the literature before and the Wi-5 project is keen to investigate this option further. From a business model perspective such a solution still needs an independent party with all the characteristics described above relating to the spectrum usage broker. However, the way this role could best be implemented is then probably by means of a standardisation organization, which is (financially) supported by the individual operators, and whose task is to create the peer-to-peer architecture, the protocol, and the fair negotiation algorithms. The body should then also be responsible for implementing and maintaining the peer-to-peer software, and to take care or police that participating APs are regularly updated.

The Wi-5 project team intends to further elaborate the Wi-5 SDN business model, in close interaction with the Wi-Fi Operator Board, applying the consecutive steps in the DAMIAN methodology (especially for designing reward/punishment mechanisms for cooperating and defecting APs), and by conducting real-life trials.

5 Conclusions

The Horizon 2020 Wi-5 (What to do With the Wi-Fi Wild West) project proposes an architecture based on an integrated and coordinated set of smart solutions able to efficiently reduce interference between neighbouring Wi-5 APs and provide optimised connectivity for new and emerging services. The main reason why the necessary cooperation and hand-over mechanisms do not yet exist is that the business models for inter-domain coordination and hand-overs were never considered when Wi-Fi was initially developed. This deliverable describes the first steps in the development of a new business model to optimise the use of available unlicensed spectrum in urban areas, public spaces and offices. Our approach is based on the following premises:

- Unlicensed spectrum is a "commons" in economic terms.
- Everybody managing a Wi-Fi AP is a service provider, including residential service consumers (prosumers).
- Under strictly defined circumstances, Wi-Fi traffic may be offloaded to 3G/4G networks.

The Wi-5 solution thus builds on a prosumer business model and it creates a new entrance in the value chain for an over-the-top Wi-Fi added-value provider to solve the "tragedy of the commons". This combination of a prosumer network model and a lean Wi-Fi added value provider has not been proposed before.

We first assessed the existing Wi-Fi-related business models by analysing their level of inter-operator collaboration versus the amount of technical coordination functionality included in the service platforms involved. We further assessed the business models by applying the DAMIAN methodology. From this analysis we conclude that:

- Business models vary mostly in terms of who is fulfilling the role of network access provider and network service packager. The role of network access provider can be taken by the core network provider or the owner of the local premises. This means that optimisation of spectral use will often be a matter of inter-provider interaction and coordination, which is inherently more difficult to achieve than intra-provider optimisation.
- The role of core network provider is superfluous. It does not have any impact on the Wi-Fi optimisation issue, whereas the ISP has routing and switching assets that could be useful within the scope of the project.
- None of the models enable the level of technical and organisational coordination that is needed to achieve the Wi-5 goals.

For the Wi-5 SDN assisted business model we therefore need to introduce a new actor: the spectrum usage broker or optimiser. The task of the spectrum usage broker is to optimise the spectrum usage of Wi-Fi APs located nearby such that the QoE of users is optimised over all users and fairly distributed among the individual users. The spectrum usage broker can achieve this by traffic steering (scheduling, redistributing traffic over Wi-Fi APs, Wi-Fi offloading to 3G/4G, etc.), but also by Wi-Fi radio resource management (channel allocation, transmit power optimisation, etc.). Fairness should be judged by an agreed policy or distribution algorithm.

The Wi-5 Operator Board and the HGI operator community still have doubts about how realistically such an actor can be initiated and maintained in a commercially viable way when it has to broker spectrum between different operators and has to include Wi-Fi offloading to 3G/4G networks as a possibility. This may be interpreted as a sign of the market disruptiveness of the new paradigm that we are introducing. We therefore analysed in more detail the use case of Wi-Fi congestion in an apartment block where the tenants all arrange their broadband access independently and have different service providers available to choose from. Wi-Fi spectrum is then just another “commons” as is the hallway, parking lot, etc., to which the vast amount of literature about the “tragedy of the commons” [3] applies. We then conclude that a solution where tenants agree that their APs will be controlled by the caretaker’s SDN controller is in full agreement with the solutions to the tragedy of the commons as described in the literature. This result encourages us to keep relying on the new model for the further development of the Wi-5 technical requirements and architecture, and fine-tune the business model where needed after the trials with the new platform have been conducted, and real consensus will be reached on the scope of the SDN-based business model.

References

[1] Baid, A. and Raychaudhuri, D., (2015). Understanding channel selection dynamics in dense Wi-Fi networks', IEEE Commun. Mag., vol. 53, no. 1, pp. 110–117.

[2] Al-Alawi, A. I. (2006). WiFi Technology: Future Market Challenges and Opportunities, J. Comput. Sci., vol. 2, no. 1, pp. 13–18.

[3] Harding, G. (1968), The Tragedy of the Commons, Science, vol. 162, pp. 1243-1248.

[4] Saldana, J., Arcia-Moret, A., Braem, B., Pietrosemoli, E., Sathiaseelan, A., Zennaro, M., (2015). Alternative Network Deployments. Taxonomy, characterization, technologies and architectures, draft-irtf-gaia-alternative-network-deployments-01. [Online]. Available: http://datatracker.ietf.org/doc/draft-irtf-gaia-alternative-network-deployments/. [Accessed: 27-Jul-2015].

[5] Osterwalder, A. and Peigneur, O. (2010). Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers, Wiley, NY.

[6] Zott, C., Amit, R., & Massa, L. (2011). The Business Model: Recent Developments and Future Research, Journal of Management, vol. 37(4), pp. 1019-1042.

[7] Zott, C., & Amit, R. (2010). Business model design: An activity system perspective, Long Range Planning, vol. 43(2/3), pp. 216-226.

[8] Baden-Fuller, C. and Haefliger, S. (2013). Business Models and Technological Innovation, Long Range Planning, vol. 46, pp. 419-426.

[9] Sorescu, A., Frambach, R.T., Singh, J., Rangaswamyd, A., Bridges, C. (2011). Innovations in Retail Business Models, Journal of Retailing, vol. 87, pp. S3-S16.

[10] Malone, T. W., Weill, P., Lai, R. K., D'Urso, V. T., Herman, G., Apel, T. G., & Woerner, S. (2006). Do some business models perform better than others? MIT Working Paper 4615-06.

[11] Kim, W.C. and Mauborgne, R. (1997). Value Innovation: The Strategic Logic of High Growth, Harvard Business Review, vol. 75(1), pp. 102-12.

[12] Porter, M. E. (1996). What is strategy? Harvard Business Review, vol. 74(6), pp. 61-78.

[13] Galbraith, J.R. (1974). Organization Design: An Information Processing View, Interfaces, vol. 4, pp. 28-36.

[14] Knudsen, T., Puranam, P., and Raveendran, M. (2012). Organization Design: The Epistemic Interdependence Perspective, Academy of Management Review, vol. 37(3), pp. 419-440.

[15] Chesbrough, H. (2003). The Governance and Performance of Xerox's Technology Spinoff Companies, Research Policy, vol. 32 (3), pp. 403-421.

[16] Chesbrough, H., Vanhaverbeke, W. and West, J. (2006). Open Innovation: Researching a New Paradigm. Oxford University Press.

[17] Dittrich, K. and Duysters, G. (2007). Networking as a means to strategy change. The case of open innovation in mobile telephony, The Journal of Product Innovation Management vol. 24(6), pp. 510-521.

[18] Adner, R., & Kapoor, R. (2010). Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations, Strategic Management Journal, vol. 31(3), pp. 306-333.

[19] Donaldson, L. (2001). The contingency theory of organizations. Thousand Oaks, CA: Sage.

[20] Al-Debei, Mutaz M., and David Avison. (2010). Developing a unified framework of the business model concept, European Journal of Information Systems vol. 19.3, pp. 359-376.

[21] Pijpers, V., De Leenheer, P., Gordijn, J. and Akkermans, H. (2011). Using conceptual models to explore business-ICT alignment in networked value constellations, Requirements Engineering, 17(3), pp. 203-226.

[22] Chesbrough, H. (2006). Open Business Models: How to Thrive in the New Innovation Landscape, Harvard Business School Press.

[23] Porter, M. (1985). Competitive advantage. New York: Free Press.

[24] Stabell, C. B., & Fjeldstad, Ø. D. (1998). Configuring value for competitive advantage: on chains, shops, and networks. Strategic Management Journal, vol. 19(5), pp. 413-437.

[25] Porter, M. E. (1979). Competitive forces shape strategy. Harvard Business Review, vol. March-April 1979, pp. 137-145.

[26] Lengnick-Hall, C. A., & Wolff, J. A. (1999). Similarities and contradictions in the core logic of three strategy research. Strategic Management Journal, vol. 20, pp. 1109-1132.

[27] Wernerfelt, B. (1984) ”A resource-based view of the firm”, Strategic Management Journal, vol. 5(2), pp. 171-180.

[28] Ballow, J. J., Thomas, R. J., & Roos, G. (2004). Future value: The $7 trillion challenge. Journal of Applied Corporate Finance, vol. 16(1), pp. 71-76.

[29] Håkansson, H., & Snehota, I. (2006). No business is an island: The network concept of business strategy. Scandinavian Journal of Management, vol. 22(3), pp. 256-270.

[30] Allee,V. (2008) “Value network analysis and value conversion of tangible and intangible assets”, Journal of Intellectual Capital, vol. 9 (1), pp. 5 – 24.

[31] Brandenburger, A.M., & Nalebuff, J. (2011) Co-opetition. Random House LLC.

[32] Ballon, P. and Van Heesvelde, E. (2011). ICT platforms and regulatory concerns in Europe, Telecommunications Policy, vol. 35 (8), pp. 702-714.

[33] Allee, V. (2002). The Future of Knowledge: Increasing Prosperity through Value Networks, Butterworth Heinemann, Boston.

[34] Value Chain Dynamics Working Group (VCDWG) (2005). Mobile services in the communication industry. MIT Communications Future programme, MIT.

[35] Eaton, B. D., Elaluf-Calderwood, S. M., & Sørensen, C. (2010). The role of control points in determining business models for future mobile generative systems, 2010 Ninth International Conference on Mobile Business and 2010 Ninth Global Mobility Roundtable (ICMB-GMR), Athens, IEEE, pp. 459-463.

[36] Coase, R. H. (1937). The nature of the firm, Economica, vol. 4(16), pp. 386-405.

[37] Williamson, O. E. (1981). The economics of organization: the transaction cost approach, American Journal of Sociology, vol. 87(3), pp. 548-577.

[38] Prahalad, C. K., & Hamel, G. (1990). The core competence of the corporation. Harvard business review, vol. 68(3), pp. 79-91.

[39] Woodard, J. (2008), "Architectural Control Points", Third International Conference on Design Science Research in Information Systems and Technology (DESRIST 2008), Atlanta GA, 7-9 May 2008.

[40] Battistella, C., Colucci, K., De Toni, A. F., & Nonino, F. (2013) “Methodology of business ecosystems network analysis: A case study in Telecom Italia Future Centre”, Technological Forecasting and Social Change, vol. 80.6, pp. 1194-1210.

[41] Barney, J. B. (1991) Firm Resources and Sustained Competitive Advantage, Journal of Management, vol. 17, pp. 99-120.

[42] Barney, J. B. (1994) Bringing Managers Back In: A Resource-Based Analysis of the Role of Managers in Creating and Sustaining Competitive Advantages for Firms, Does management matter? On competencies and competitive advantage. Lund, Sweden: Institute of Economic Research, Lund University. The 1994 Crafoord lectures: pp. 1-36.

[43] Barney, J. B. (2002). Gaining and Sustaining Competitive Advantage. Prentice Hall.

[44] Kraaijenbrink, Jeroen; Spender, JC and Groen, Aard (2010) The resource-based view: A review and assessment of its critiques. MPRA Paper No. 21442.

[45] Dittrich, K., Koers, W., Berkers, F., Nooren, P. (2015). Developing a methodology for systematic analysis of competing value networks in converging markets. Paper presented at the Competicon - International Competitiveness Conference, 19-20 January 2015, Copenhagen, Denmark.

[46] Rebbeck, T. and Yardley, M., (2014). Public Wi-Fi Networks in a 4G World. Report for Arqiva.

[47] Studer Ferreira, L., Pichon, D., Hatefi, A., Gomes, A., Dimitrova, D., Braun, T. & Correia, L. M. (2014). An architecture to offer cloud-based radio access network as a service. In Networks and Communications (EuCNC), 2014 European Conference on (pp. 1-5). IEEE.

[48] Kreutz, D., Ramos, F. M., Esteves Verissimo, P., Esteve Rothenberg, C., Azodolmolky, S., & Uhlig, S. (2015). Software-defined networking: A comprehensive survey. Proceedings of the IEEE, vol. 103(1), pp. 14-76.

[49] Schulz-Zander, J., Suresh, L., Sarrar, N., Feldmann, A., Hühn, T., & Merz, R. (2014). Programmatic orchestration of wifi networks. In 2014 USENIX Annual Technical Conference (USENIX ATC 14) (pp. 347-358). USENIX Association, Philadelphia PA.

[51] Ali-Ahmad, H., Cicconetti, C., La Oliva, A., Mancuso, V., Reddy Sama, M., Seite, P., & Shanmugalingam, S. (2013). An SDN-based network architecture for extremely dense wireless networks. In Software Defined Networks for Future Networks and Services (SDN4FNS), Trento.

[52] Sedlacek, I. (2015), 3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Access Network Discovery and Selection Function (ANDSF) Management Object (MO) (Release 12). 3GPP TS 24.312 V12.9.0.

[53] Youchun, Z. (2012). Go with WiFi for Better Mobile Experience. ZTE Technologies (6), online at http://wwwen.zte.com.cn/endata/magazine/ztetechnologies/2012/no6/articles/201211/t20121121_370651.html.

[54] IEEE (2003) 802.11h, IEEE Standard for Information technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 5: Spectrum and Transmit Power Management Extensions in the 5 GHz band in Europe, The Institute of Electrical and Electronics Engineers, Inc. New York, NY.

[55] Den Hartog F. (2015). Realizing RWD-057 use cases with SDN. Contribution HGI02641 to HGI.

[56] McKeown, Nick, *et al*. (2008) OpenFlow: enabling innovation in campus networks. ACM SIGCOMM Computer Communication Review vol. 38.2, pp. 69-74.

[57] ONF (2014), SDN Architecture Overview, Version 1.1, ONF TR-504.