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Abstract

The 21st Century is the century of digital infrastructures. The Internet and global mobile telecommunications infrastructures are increasingly converging at different layers. This paper is concerned with the understanding of the innovation of such converged mobile digital infrastructures. Digital infrastructures are established and operated by a heterogeneous collection of public and private organisations, each governed by own interests in the collaborative arrangement. The creation and distribution of value is collaborative, yet governed by conflicting interests. Two separate strands of research explore collaboration, conflict and control in digital infrastructure innovation. Research on tussles between participating interests emphasise the need to understand the complex relationships between collaboration and conflict. Research on architectural control points emphasises individual organisations' ability to exercise control and generate value. So far these two research strands have not been subjected to a synthesis. The aim of this paper is to provide such an initial theoretical synthesis in the form of a tussle and control framework. The paper defines the concept of control points from a socio-technical point of view and applying this concept to an analysis of digital infrastructures, the tussles between stakeholders, and the discussion of value networks and innovative business models. This contributes to a finer granularity of the analysis of conflict, collaboration, and control on digital infrastructure innovation.

Keywords: control points, digital infrastructures, tussles, socio-technical, value networks, and business models

1 Introduction

Utility infrastructures delivering water, electricity and gas, and transportation infrastructures such as roads and railways, are critical for contemporary creation of value. The development of a global telegraph infrastructure in the 20th Century saw the emergence of electronic infrastructures as integral to global business (Standage, 1998). The 21st Century heralds the age of the digital infrastructure as digitalization shake up existing boundaries between established interest groups, providing new opportunities and challenging existing revenue models (Tilson et al., 2010). Digital infrastructures are established and operated by a heterogeneous collection of stakeholders drawn from both private and public organisations. The Internet was originally established on the basis of the alignment of interests between the government agencies, universities and research laboratories promoting it, but opening the infrastructure to a range of interested parties since the Mid-1990s has resulted in a much more complex arrangement. Furthermore, the convergence and overlay of the Internet with global mobile telecommunication systems with radically different control mechanisms, such as centralised ownership structures and payment termination embedded in SIM cards, has paradoxically led to further complexity and divergent interests in the increasingly unified mobile Internet (Clark et al., 2005; Herzhoff, 2011). Information Systems research has so far largely failed to comprehensively explain the dynamics of digital infrastructures (Tilson et al, 2010). Two strands of research investigate issues of collaboration, conflict and control in digital infrastructures; The study of tussles in digital infrastructure innovation; and research into architectural control points.

Research on global telecommunications infrastructures emphasises the dual need for organisations to engage in collaboration forwarding the infrastructure and to nurture own organisational interests. Infrastructure dynamics governed by such complex conflicting interests can be characterised in terms of tussles between participating interests bound together in paradoxical situations of collaboration and conflict (Clark et al., 2005). Understanding the complexity of and the challenges confronted by telecommunications operators requires multiple layers of analysis, especially when considering the provision of digital services. One of the main characteristics of the expected changes is the presence of variable socio-technical triggers in the operator's value networks, leading to tussles and network design changes (Herzhoff et al, 2009a). One major characteristic of a digital infrastructure is the active role of a diversity of stakeholders with direct and indirect interests in the network operation through tussles. This paper considers the dynamic interactions and strategies among stakeholders, making use of the analytical domains proposed by Lyytinen and King (2002): the innovation space, the marketplace, and the regulatory regime.

Another strand of research stems from investigations into architectural modularity, control and the generation of value in networks (Woodard, 2008; Trossen & Fine, 2005). This research emphasises architectural control points as a means of understanding control- and value discussions. This paper analyses the concept of control points as a technical concept applied to mobile network architectures, which has been transposed and extended as a socio-technical variable in the networking literature. Mobile telecommunication networks are presented with a challenge from the convergence of mobile telephony networks with the Internet (Herzhoff, 2009e). They present a level of complexity from the demand of new services and interoperability of issues within networks, e.g. network sharing. The term "control point" has rarely been defined, yet is used in a variety of contexts, often mixed with economic concepts such as two-sided markets, value networks, value chains, or technical network terms such as gateways, bottlenecks, standards, tussles and granularity (Herzhoff et al, 2009b). Control points are often regarded as a network concept linked to the risks associated with the shift towards symmetric and asymmetric transactions in the value network (Herzhoff et al, 2009c).

This paper focuses on the understanding of mobile digital infrastructure innovation and engages in a theoretical discussion of control, collaboration and conflict in the innovation of mobile digital infrastructures. The aim of this paper is to provide an initial theoretical synthesis in the form of a tussle- and control framework. The paper defines the concept of control points from a socio-technical point of view and applying this concept to an analysis of digital infrastructures, the tussles between stakeholders, and the discussion of value networks and innovative business models. The discussion of architectural control points from a tussle perspective represents a powerful analytical perspective when applied to complex, multi-player domains such as mobile digital infrastructure innovation.

The aim of the paper is to alleviate the problem of conceptualising digital infrastructure innovation (Tilson et al., 2010) from the perspective of detailed value decisions and contributes through bringing together two separate strands of research, which in turn yields a simple, yet powerful, initial theoretical conceptualisation.

Section 2 of this paper outlines the current discussion of digital infrastructure innovation in terms of both tussles and control points. Section 3 synthesises the discussions of tussles as both collaborative necessity and conflicting interests with that of control in digital infrastructures expressed through the concept of architectural control points. This results in a tussle and control point framework for mobile digital infrastructure innovation, which also is related to the determination of value in networks. Finally, section 4 concludes the paper and draw up further research directions.

2 Digital Infrastructures

Relying on technical processes of digitizing analogue information into digital bit-streams, which in turn relates to socio-technical processes of digitalisation, digital infrastructures can be characterised in terms of paradoxical relations between both stability and change, and generativity and control (Tilson et al., 2010). Compared with analogue- or transportation infrastructures, this results in the potential for disruption when established social- and institutional arrangements are challenged and participating interests continually will be engaging in assessments of how to both engage in collaboration with other parties, and yet cultivate own interests. Due to regulatory pressures and issues of infrastructure capacity, a number of properties are emerging in mobile digital infrastructures. One of these is the concept of network sharing, which is increasingly popular amongst some heterogeneous user communities, designers, regulators and other social actors. This is leading to convergence between the Internet open model of innovation and the closely governed model of innovation in mobile telecommunications. In the open model, any new information technology capability, designer or user group can be added provided it conforms to the architectural principles of the Internet. While technical processes of digitising leads to a range of possibilities for flexible re-allocation of responsibilities, in socio-technical terms, the desirability of such re-allocation will greatly depend on individual participant's interests. As an example, digitising voice connections through mobile Voice over IP (VoIP) technology, can result in a variety of outcomes in terms of the socio-technical arrangement of the digitalisation resulting from VoIP protocols applied in mobile digital infrastructures (Herzhoff, 2011). The result can vary from law-suits between network operators and mobile VoIP service providers and to close collaboration between the two (Herzhoff, 2011). The social and technical demands on digital infrastructures are becoming increasingly heterogeneous, leading to an increase in communication capabilities and promoting distributed computing. Whilst this increases the probability that conflicts will emerge, it also provides opportunities for their mediation and resolution. The following subsection will discuss the issue of tussles as part of the discourse on the socio-technical component of the network layer architecture.

2.1 Mobile Digital Infrastructures

A mobile digital infrastructure is formed by an ecology of devices and services aiming to provide a seamless experience to the network users. Enabling technologies within this type of network promotes flexible, agile, dynamic and self-evolving networking capable of coping with unforeseen socio-economic demands, e.g. user/network operator/service provider, so that the seamless goals can be achieved. There are three components contributing to the definition of a digital infrastructure (Mobile VCE, 2007, 2008):

Social factors: This component is the voice of the user perception when using services provided by a digital infrastructure. It should be a seamless service, ideally with a featured configuration provided free (or at minimal cost), and requiring little user awareness of changes in formats, protocols or quality of service.

Economic and business factors: This component is the voice of the network operators. In an operational digital infrastructure it implies the use of an intelligent decision making process. Computational algorithms should provide a working framework to optimise allocation of the resources available within networks. These should be informed by, and configured according to, advanced dynamic service level agreements, discovery service intelligence, digital market oriented application, and regulatory requirements.

Network factors: A digital infrastructure shall be adaptable when network expansion is required. This adaptability is understood in terms of network capacity and protocol negotiation.

In general, the design of communication infrastructures cannot be considered in an entirely isolated design of each part of the infrastructure without overall insight in the end-to-end delivery of services as low-level services may prove redundant or ineffective when applied at aggregate levels (Saltzer et al.1984). The increasing number of conflicts caused by the convergence of information and communication technology puts pressure on the existing infrastructure (Clark et al., 2005; Tilson et al., 2010). Parties with conflicting interests get increasingly incentivised to actively engage in interference. These interferences increase the complexity of the infrastructure and may lead to breakdowns in operation. A possible strategy to overcome these problems is the development of digital infrastructures in terms of structural flexibility, e.g. network virtualization, and control flexibility. This constitutes a dynamic market approach (MVCE, 2008; Irvine, 2002; Bush, 2009). The idea of digital infrastructures faces three main challenges: (1) the role played by heterogeneous systems in terms of transmission power, frequencies, range, quality of service (QoS) requirements, spectral efficiency, and standards (Grøtnes, 2009); (2) the limited or no communication between these systems; and (3) the way systems change rapidly and the way digital infrastructures have to adapt quickly without degradation of service (Herzhoff et al, 2009d).

A digital infrastructure cannot be singled out as a network demand or capacity tussle mediator. The common use of expressions such as “a network capable of coping with unforeseen demands” or “a network able to resolve tussles on demand” represent partial or incomplete views of what a digital infrastructure can do. A digital infrastructure is not able to resolve, using its self-contained resources, all tussles generated internally. A requirement for digital infrastructures is not a justification for an expansion of the network that does not take into account the variations in usage the network might have. A digital infrastructure shall not be the replicator or amplifier of current network hierarchy, or a computational tool to extend current IP networks and protocols (Herzhoff, 2009a& 2009e.).

2.2 Tussles

Clark et al. (2005) suggest the concept of *tussle* in the context of network architecture design. They define a tussle as “the ongoing contention among parties with conflicting interests” (p. 462). Clark et al. (2005) further specify that in these tussles “different parties adapt a mix of mechanisms to try to achieve their conflicting goals, and others respond by adapting the mechanisms to push back” (p. 462). The term *tussle* is defined as an intense disagreement, or dispute, between parties who nonetheless have significant interests in collaborating. This concept can help explain a number of important changes at the core of mobile network innovation.

It is necessary to lay down some basic assumptions about the very important distinction between competition and conflict (Economides, 1992 and 2006). Many studies, including the work by Clark et al. (2005), lack the conceptual clarity to differentiate between these two concepts. Others argue that this mainly results from the fact that the precondition of both competition and conflict is goal incompatibility. However, these incompatible goals can also be the result of contested resources, incompatibility of roles or incompatibility of values. Thus, competition is distinct from conflict. There are four different schools of thought on how the distinction between competition and conflict plays out. The first makes the distinction based on awareness: in this line of thought conflict is seen as a situation of competition in which parties are *aware* of their incompatible goals. The second school of thought examines how competition is regulated. Hence, competition becomes conflict if it goes beyond the limits of regulatory norms. The third school of thought bases the distinction on behaviour: two parties might compete and yet not be in a state of conflict, and will continue to cooperate on a daily basis. The behaviour of each party might be determined by different and incompatible goals, but this is not necessarily the precondition for a conflict to emerge, since this also requires some sort of motivation to interfere. This difference can be described as one of parallel striving (*competition*) and mutual interference *(conflict*) (Herzhoff et al, 2009d). The fourth school is based on Luhmann's (1995) systems theory. Competition is here seen as a descriptor for the environment of the organization projected by one party, but direct interaction is not a necessary precondition. However, if direct interactions take place the possibility emerges for one party to communicate a “no” (Luhmann, 1995). It is this negation that may lead to the emergence of a conflict system.

Cyberlaw scholars concerned with the legal regulation of the Internet against abuse provide a complementary view of infrastructure development (Tilson et al, 2010; Herzhoff et al, 2010; Eaton et al., 2010). Benkler (2005), for example, suggests that appropriate regulatory frameworks in a converged network should orient themselves towards democratic values and he proposes an approach to develop descriptive models based on how laws concentrate or distribute control over production and exchange of information. Lessig (2000) identifies four types of modalities of regulation: (1) Laws, (2) social norms, (3) markets and (4) architecture or code. While Lessig applies these modalities within the limited context of regulation, Murray and Scott (2002) argue that the modalities of regulation are not limited to regulation but are part of any form of control system.

Herzhoff et al. (2009a,b,c,d) study mobile VoIP and mobile network sharing. In this context, network sharing is a cost-effective way of deploying 3G networks, and it has both benefits and drawbacks. Infrastructure sharing for example can be used both in the start-up phase to build coverage quickly and, in the longer term, to build cost effective coverage for areas of low reception. From the point of view of competition, many operators are satisfied with the arrangements established for sharing when it has a vertical distribution in the different telecommunication layers. However, changes in the sources of economic revenue are making it more common for operators to be willing or pushed to share on a horizontal basis — layer to layer- with other mobile operators.

In networking terms, tussles test the strength of control in a value network. If the tussle is too intense or cannot be resolved, then the control is completely overtaken by one player – hence it stops being shared but instead converts itself into a laissez-faire leader – or negotiations might occur, presenting a wide range of possible solutions. The concept of tussle therefore seems to stress more the dynamics of the conflict situation and the different mechanisms the contesting parties put in place. This brings us to the discussion of control and control points in digital infrastructure innovation.

2.3 Control Points

This section discusses the possible role of control points as an aid to understanding the complexity of digital infrastructure innovation. There are diverse discussions on the complexities of network architecture and modularity (Voss, 2009; Woodard 2008). With the increasing importance of alliances of participant stakeholders with different, and possibly diverging, interests, the issue of control and the associated process of organising collaboration under conflicting interests is brought to the fore. Hanseth and Lyytinen (2010) propose a high order discussion model on control and from part of a set of organizing principles in which the Internet – and the networks linked to it – is composed of multiple layers of distinct information technology capabilities that carry out similar functions at different layers. Tilson et al. (2010) argue that digital infrastructure development is a continual process governed by; the paradox of change with reliance on stability; and the paradox of control coexisting with generativity. These conflicting interests regarding infrastructure developments can arise from a variety of socio-economic areas. In the case of the Internet, for example, the design is distributed between a large set of architects and developers, user communities and forms of governance (Hanseth & Lyytinen, 2010). The control of different network capabilities is separated and distributed, and the control forms are loosely coupled through architectural network principles. Hence mobile networks usually present one or more actors actively seeking the control of a whole section of a mobile network.

The notion of “control points” has been used in several contexts, for example, to characterise essential architectural design decisions (Woodard, 2008), or to characterise the generation of value (Trossen & Fine, 2005). The concept was developed by the Value Chain Dynamics Working Group at MIT (Trossen & Fine, 2005) in order to understand how commercial benefit is gained from business models emerging in and around the telecommunications industry. Woodard (2008) defines architectural control points as “*system components whose decision rights confer architectural control over other components*” (p. 361). This effect can be small but also powerful, influencing the whole architectural landscape. Control points can broadly be defined as points at which management can be applied, and any encapsulated functional element of a system can be a control point (Trossen & Fine, 2005).

Control points enable the controller to exercise power over other players or actors of a socio-technical ecosystem. They represent a socio-technical mechanism expressing the boundaries of areas of economic power in the value networks identified within a telecommunications network. Value networks are defined as: *“a dynamic network of actors working together to generate customer value and network value by means of a specific service offering, in which tangible and intangible value is exchanged between the actors involved”* (De Reuver, 2009).

Trossen & Fine (2005) show how control points can be identified and implemented within communications architectures, and how they can facilitate the construction of potential business models that in turn can be evaluated in terms of viability and sustainability. This manner of use of control points also shows how external triggers, arising from different domains (e.g. changes in technology, the business cycle, industry structure, regulatory policy, customer preference, capital markets and corporate strategy), can lead to control points increasing or decreasing in importance, which in turn affect the strength of business models.

Control points are defined by four parameters (Trossen & Fine, 2005): Interchangeability, demand, value, and time. The value of a control point depends on interchangeability and demand. Time affects all three parameters. Control is exercised via business, regulatory, and/or technical means. The notion of control point suggested in this paper strikes a balance between Woodard’s (2008) specific emphasis on architectural control, and Trossen & Fine’s very broad perspective on control points. While this paper does not consider that any communication interface can be managed as a control point, it also does not limit itself to just architectural components.

An interesting example to introduce the ways in which control points may be used to analyze stakeholder relationships can be taken from the sharing of network infrastructure when deploying new 3G networks. Infrastructure sharing is a demonstrably cost-effective technique, particularly in rural areas, and rapidly expands network coverage. Sharing agreements provide the highest savings in cases of low traffic demand and greater efficiency is achieved by pooling resources. For these reasons regulators are eager to provide regulatory stimuli for its implementation. However, an important drawback is that tussles occur between network managers vying for the temporary or permanent control over, or influence on, the regulations governing sharing. These tussles are dealt with by exercising different levels or layers of control at different points in the value chain.

In the next section control points will be discussed in more detail, and the development of digital infrastructure innovation will be examined, taking into account the tussles between the network stakeholders.

3 A Tussle Model for Mobile Digital Infrastructures

An increasing problem faced by telecommunication network operators today is the need to monetize their network assets in the face of diminishing margins on voice and data traffic. There are already many examples where virtual operators provide services using the infrastructure of a classical network provider. The question is then how can networks be shared fairly, between many providers, if providers are unwilling to exchange full information about their subscriber bases? Even if they were to, would regulators object on the basis of competition and privacy? Any practical solution must take into account all the stakeholders — users, network, service and application providers, manufacturers and regulators — and their various goals and aspirations. The first step in supplying a viable, long-term solution is to identify the ever-present tussles that result from the individual goals and aspirations between the stakeholders or entities (Clark et al., 2005).

3.1 A Tussle and Control Framework

Tussles can happen between and within these four different socio-technical systems. The *infrastructure* system comprises the network itself, the data pipe, and the technology enabling the transport. It can be based on different types of technology (Wifi, 3G, LTE etc.). The *service* system can be of any type, e.g. in the case of mobile VoIP, a voice service. The *regulatory* system consists of all regulatory functions such as spectrum and setting of interconnection charges. Finally, the *use* system consists of all functions in the use domain of a specific service and a specific infrastructure, e.g. the device, the operating system and the user interface. Combining the discussion of regulation with infrastructure, service, and use provides a comprehensive perspective on the aspects relevant to a discussion of control points and tussles in flexible mobile network innovation. The model presented in Figure 1 uses these four elements to explain the relationships between the tussles elements relevant to this analysis.

The figure illustrates the conflicts or tussles that may occur within and between socio-technical entities in terms of the existing infrastructure, the services offered by the various providers, the regulatory system, and market demand (Herzhoff et al., 2009a). Each of the four socio-technical systems presented above has certain functions, which can also be described as control points. These control points can follow different modalities. They can be hierarchical, market-oriented, design-oriented, or community-oriented. In a market environment, control points are defined by the actor(s) interested in the maximum revenue, or stake of control. However they will also expect to limit the scope of usability when subject to regulation. Regulation can exclude certain types of control point (e.g. compulsory provision of emergency services) or determine the limits of power for certain control points (e.g. limitation in charges or service pricing). Depending on their role in the revenue value model, an actor could have a set of control points defined based on regulation, which leads one to think that control points are not an off-the-shelf definition but vary depending upon the circumstances in which regulation is applied.

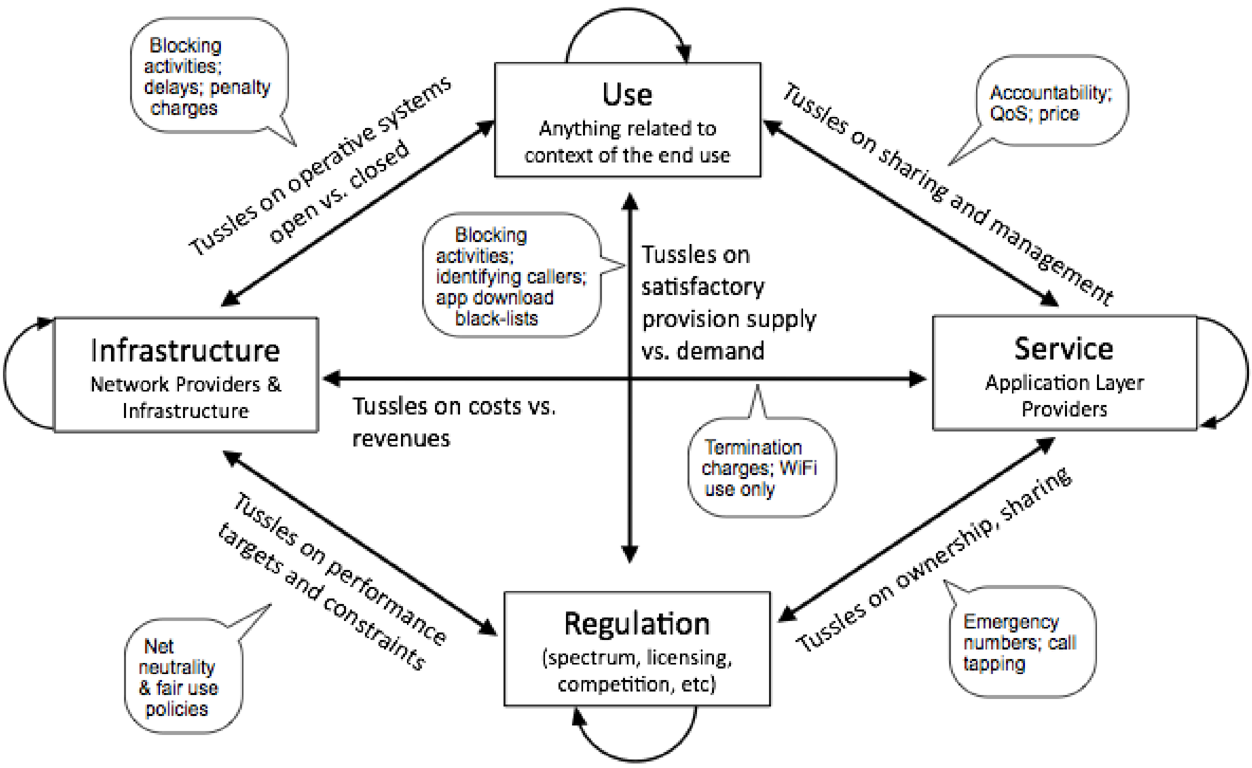

Figure 1. Tussle and control model with examples from mobile network operator tussles.

3.2 Control and Tussles in Value Networks

The model proposed model can be extended to value-added networks. Business models and value chains can be defined in terms of "the way a network of companies intends to create and capture value from the employment of technological opportunities" (Faber et al, 2003). Fine (1998) was one of the first researchers to work on comparative studies using the approach of value chain dynamics, cross-industry comparisons, and the exploration of life-cycles in complex value chains. Fine (1998) proposes a double helix model, which for telecommunications captures this life cycle in four phases — integration, market differentiation, verticalisation and disintegration. It visualizes a complex trigger dynamic analysis that leads to the observed integration/disintegration effects. Trossen and Fine (2005) extend this to develop analysis methodologies that allow for segmentation into value chains or value networks. Fine (1998) also discusses the bullwhip effect, whereby a complex value chain can amplify changes in demand, the impact being increased volatility of demand further up the supply chain. While this more traditionally relates to inventory-based value chains, a similar behaviour can be observed in telecommunications (equipment stock) and computer industry (investment in R&D). Mitigating this effect, within the context of future network design, is desirable.

Clark and Blumenthal (2007) apply a socio-economic perspective to network architectural design in a systematic manner and thereby shape the foundation for trust-to-trust principles. Sollins and Trossen (2007) extend the "Design for Tussle" concepts towards a vision for a flexible execution environment that incorporates tussles – and the concerns that drive them – directly into the formation of the dynamic execution environments. As an example of such evaluation, Trossen & Fine (2005) outline the potential application of such an evaluation tool in the area of VoIP, informing decision makers at the regulatory level, in this case the FCC in the US market, on the required speed of regulatory action, a crucial part of an overall design process.

Finding a method to identify the creators of value is a major concern. Eaton et al. (2010) propose the use of control points in the mobile Internet for the determination of value networks in a two-stage model that includes the creation of a map of the various constituent actors within the industry. This map serves to illustrate the businesses that may exist across the industry, and control points are used to examine where and how members of the value network can extract value and the use of triggers in order to understand the sustainability of this economic power given the impact of external factors.

Faber et al's (2003) definition of the business model highlights the networked character of digital infrastructure innovation, the value creation and captures involved in the trade-off, as well as the issues connected with technology design (Ballon, 2009). In doing so, there are three critical dimensions of analysis (Ballon, 2009) mirroring the model in Figure 1; Industry structure and value network; functional and technical architecture; and value creation and capture. Based on the empirical evidence collected by the authors, there are no strong indicators to challenge this description of the fundamentals of tussle creation and management between operators as proposed in figure 1. The authors encountered a mirrored reflection of the high-end tussles models on the analysis of value networks completed by Ballon (2009): for each component of the proposed model by Herzhoff et al. (2009), there is a value component in the model proposed by Ballon.

If the tussle model proposed an ontology considering the potential relationships between the actors influencing the tussles, then the business model ontology incorporates four different levels of a business model: a strategic, functional, financial, and value configuration level. At the strategic level, a business model is concerned with the value network configuration, i.e. setting up roles and relations between actors, and the physical and virtual flows between them. At the functional level, a business model describes the architecture of a product or service, which is determined by a specific configuration of modules, interfaces and intelligence. At the financial level, a business model describes the cost and revenue sources, as well as the distribution of flows for the actors involved. Together, these three levels contribute to the fourth and final level of a business model, i.e. the value configuration.

We propose that within complex and converging business and digital infrastructures, characterised by value co-creation within a large "industrial architecture", research should not just focus on any clear-cut value proposition, but rather on the process of value construction leading to various value configurations. This deals with the way in which actual value is created in the market. While specific design choices also need to be made at this level, the value configuration can also be viewed as the logical outcome of business model design choices made at the previous levels. Figure 2 illustrates the basic, bi-directional relations between the different levels.

In reality, a range of complex, both direct and indirect, bidirectional relations between the different levels exist. Also, which particular relationship is focused on and in which 'direction' the impact is studied, depends upon particular cases and contexts. One of the tasks of a design approach that takes into account contextual contingencies will be to identify the realistic scope for choice available to technology producers and users at the various levels and subsequently work out the impact of the various 'degrees of freedom' among the different levels. However, in order to enhance the clarity of the initial ontology, it is proposed here as a point of departure that the value network is the primary agent, which designs and uses a functional architecture and shares cost and revenues, and that the value configuration is the primary outcome of the business modelling process.

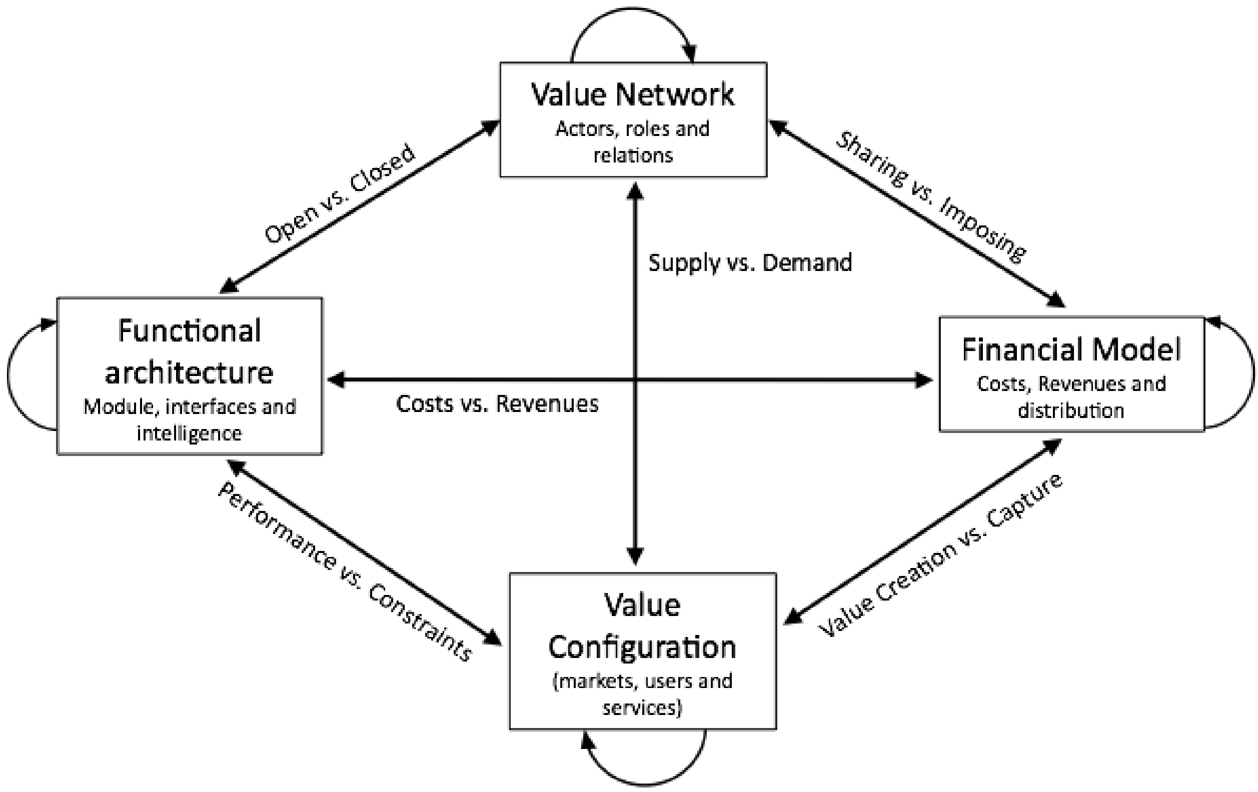

Figure 2: The high-end tussle model transposed to a value networks model (based on Ballon (2009, pp217)

Finally, a value network consists of actors possessing certain resources and capabilities, which interact and together perform value activities or roles, in order both to create value for customers and to realise their own strategies and goals. It is the result of organisational and strategic design, in which control points as an analytical tool provide insightful understanding of the forces in place for the development of business models. The four levels of this framework and their interrelationship need to be detailed, and subsequently the levels or domains need to be extrapolated into a number of parameters, i.e. a the crucial configuration parameters that would need to be addressed by any business model aiming for new or improved digital infrastructures products or services.

4 Conclusion

The concept of control points, as part of a methodological tool for analysis of the development of network design, has been successfully transposed from its technical origins to become a socio-technical variable. By including in the analysis the multiple relationships, tussles and ambiguity between stakeholders, control points can become a tool that adequately addresses the complexities attached to the development of digital infrastructure design. Further work is required to complement the understanding of the tussle concept. Perhaps the goal ought to be the development of a tussle taxonomy, which clarifies the important distinctions between tussle, conflict, collaboration, and competition. Some tussles will continue to be external to socio-technical approaches and need to be properly identified.

Although control points are contributing significantly to the analysis of and planning for tussles, there are some shortcomings to the approach. It is necessary to complement this analysis with a revision of the combination of methods used to exploit value chain dynamics in conjunction with other approaches as part of an analysis of metrics. Furthermore, a conceptual clarification of control points will be part of this process, e.g. the role of tussles, granularity of the analysis, value web, etc. Particular stress must be placed on understanding what is controlled, e.g. network behaviour, revenue, resources, functionality, generativity, innovation.

By including a socio-technical metrics definition in our work, we have opened a number of research opportunities, which have arisen from the development of socio-economic metrics for network selection algorithms. Metrics that will be investigated in future might include: 1) profitability metrics, e.g. profitability per byte; 2) trust metrics, for example based on user rating or network strength (e.g. other people the user knows using the network); 3) consumer surplus metrics, not only based on network strength but also on other cost profiles converted in utility; and 4) pay-off metrics, e.g. taking into consideration tussles between users and operators.

There are many open questions on how to manage the socio-economic impacts and technology implementation, particular in mobile digital infrastructures. At present, service-level agreements (SLAs) are the main vehicle used to translate commercial service requirements into the technology domains, which leads to rather rigid network configurations aiming only to cater for peak-demand provision rather than conflict/tussle resolution (Abou Chanab & El-Darwiche, 2007; Al-Debei & Avison, 2010).

There are metrics to define technical network requirements, but none to capture the non-technical aspects. The most common ones, including exchange, trading mechanisms policies for data flows and network cooperation, have been dealt with from a purely technical view. Collaboration in networks to date has been mostly in the form of; 1) SLAs where one provider piggybacks the other, such as providing the fibre backbone; 2) other arrangements include site sharing between mobile operators; or 3) more recently base station sharing (Fransman, 2001). These approaches are usually non-dynamic and the shared resources are prescribed.

Collaboration and resource sharing across networks is still in the very early stages of its development. Building networks and planning for their growth have been linked to backward compatibility and deployment of gateways, which in turn has generated complexity for any type of collaboration between networks. This has made the operation and dynamic assignment of resources rather difficult, and resource sharing leads to tight coupling between networks, thus limiting their independence.

A number of questions have been raised, which are open for further research:

- How can control points be used to enhance the design and innovation of flexible competing and co-operating networks?
- What are the effective exchange mechanisms for resources between cooperating networks, and how well will they operate to resolve tussles in real-world scenarios?

- How can control points help to solve tussles and conflicts during the design process?
- Can the concept of control points be abstracted sufficiently to provide a framework for business value networks?
- What is the role of control points in establishing successful value networks, which can support innovative digital markets by themselves?

Control points have been used at the network, management and content and business model layers as a powerful tool to understand challenges brought about by the evolution and fast innovation of the technologies described. This method of analysis can be used to understand the relationships between the different stakeholders in the ecosystem, the roles and functions they bring to the value chain and the short and long term effects of those relationships.

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