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Conference Paper

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28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd August, 2017

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Elaluf-Calderwood, Silvia; Liebenau, Jonathan; Rossi, Enrico (2017) : Changing Markets in Operating Systems: A socio-economic analysis, 28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd August, 2017, International Telecommunications Society (ITS), Calgary

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Changing Markets in Operating Systems; a socio-economic analysis

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1. Markets in operating systems

The distinct characteristics of markets for operating systems need to be understood in full, this is driven by current concerns about competition and fragmentation. In this paper we provide an in-progress report on our analysis of the effects of operating systems markets on trade and innovation, and on the significance/impact for the architectures of networks in the digital economy. As an academic study, we have focused on the conceptual foundations of these topics, but we also show their business and policy significance.

We provide a review of the various market definitions of software operating systems to understand their economic characteristics from a socio-technological view. From the early dominance of IBM's OS/360 to UNIX-related systems and the disk operating systems [DOS] of IBM and Microsoft through to Apple's Mac OS and Google's systems [Chrome OS and Android], there has been a succession of dominant players. The reaction of the information technology and related industries to this dominance is the key to understanding the dynamics of competition in these markets.

We consider the economic theory behind markets in platforms and its relationship with operating systems. That rests on a reinterpretation of the economics of infrastructure and addresses concepts of ownership, control and market dynamics, and their regulatory significance. Finally, we provide some policy recommendations based on our initial competition and market analysis. Our research work is still in progress and we expect further developments in the near future.

The questions we address are:

- i) Where does control reside in an ecosystem of devices, software, and services? Note that we distinguish between control and ownership.
- ii) What is the significance of application and protocol standards in a heterogeneous network?
- iii) What is the significance of application technologies with regard to use?

In the light of these questions, we show how to analyze the current and potential markets in platforms and their relationship with operating systems. That rests on a reinterpretation of the economics of infrastructure and deals with problems of ownership, control and market dynamics, and their regulatory significance. In our

current work, we apply a novel approach to market definition, market power, and property rights for operating systems.

2. The Basics

2.1 Architecture

We start with a simple assumption about the separation of control from ownership in the case of operating systems and consider what both their separate and combined relationships might be to competition in platforms and applications.

The architecture of operating systems was based on three principles:

- They were to be closed systems with limited regulated access to other networks,
- New systems within the OS and/or applications embedded or integrated were based on a common computing language and functionality,
- Back-end network management and security was a norm.

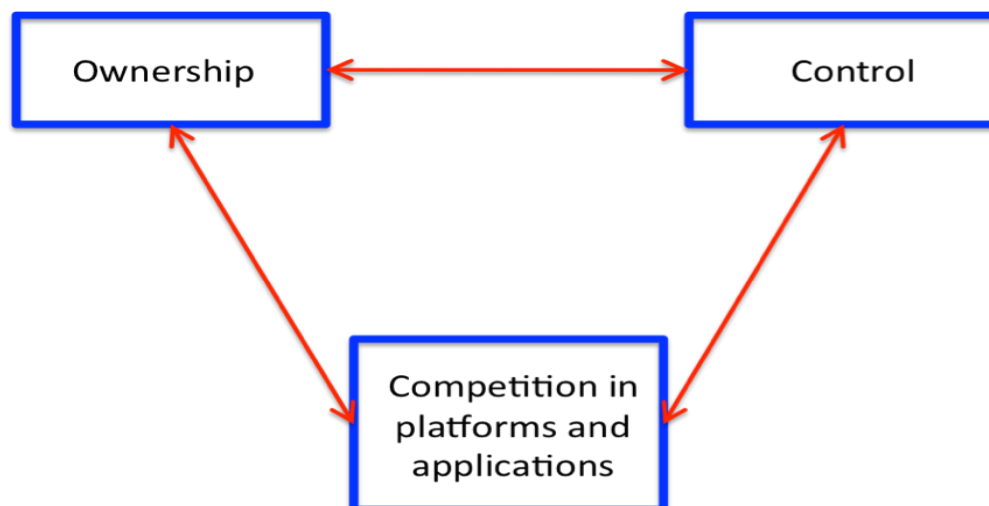


Figure 1. Establishing relationships of power structure in OS

2.2 Diversification of platforms

The development of operating systems platforms has led to a reclassification of the term platform to understand the convergence that is the source of tussles in the emergent digital market. This reclassification has three forms of convergence: porting tools, meta-platforms and functional convergence. Therefore, platform convergence reduces multi-homing costs and increases platform and app competition. We explain the three forms of platform convergence in the following terms:

2.2.1 Porting tools

The software reduces the cost of developer platform multi-homing by reducing or eliminating porting costs. These tools are the equivalent of plug converters. Instead of creating a single, standardized plug and outlet, they allow relatively inexpensive porting of plugs to an array of incompatible outlets. However, unlike the plug example, converters in the present context enable developer conversion rather than user conversion. They, like others, benefit from opportunities to reduce costs by encouraging platform multihoming. This reduces the likelihood of platform lock-in, increasing competition among platforms because it provides developers with reduced entry costs.

Despite these tools, however, porting still faces disadvantages. First, ambitious porting projects have been delayed or scuttled due to the technical difficulty of porting apps without losing functionality or creating malfunctions. Second, even successful porting tools do not altogether eliminate porting costs. While popular “superstar” apps are likely to be ported despite such costs, a tail end of less popular apps are likely to remain single-platform even with readily available porting tools.

It is our general view that:

- The proliferation of porting tools tends to make durable market power less plausible in a variety of settings, including mobile OSs and mobile app stores.
- Porting tools increase the competitive significance of non-traditional devices.

2.2.2 Meta-platforms

Meta-platforms are software development platforms that sit on top of other platforms. The archetypical meta-platforms are internet browsers and associated cross-browser coding languages such as HTML5. Meta-platforms reduce developer porting costs while also acting as a converter for users. The result is easy multi-homing by both users and developers. This, in turn, reduces the likelihood of platform lock-in, reduces platform entry costs and increases competition. The essential problem with these meta-platforms is that they often cannot take advantage of each underlying platform’s unique APIs and features. This problem stymied Java 2 Mobile (“J2ME”) and continues to work against both HTML and Java-based meta-platforms.

2.2.3 Functional convergence of platforms

Functional convergence occurs when two distinct platforms start to offer the same functionality. This is distinguishable from other forms of convergence because it does not imply porting or technical/coding convergence of apps. Examples of this include Amazon and Facebook are examples of platforms that over time have added an enormous amount of functionality that crosses into traditional search and other functions. The functional convergence of platforms has limited impact on developer multi-homing, but it introduces new competition for users between successful platforms.

It seems to be that the apparent market power among existing platforms is illusory. In practice, convergence increases the universe of possible substitutes. Even the threat of convergence could thwart monopoly pricing and encourage innovation.

This raises questions of how to reduce the threat of platform lock-in. This is possible since multi-homing on both sides of the market makes tipping unlikely. Furthermore, platforms that have seemingly already tipped may still be vulnerable to new, disruptive meta-platforms, porting tools, or functional convergence.

The key is to be found in the ways to increase app competition. In practice, apps previously limited to a single platform face new competition, particularly with respect to meta-platforms. Also, functional convergence pits leading apps that previously lacked overlapping functions against one another.

The proliferation of platforms to new device types also increases competition because devices are more likely to run multiple competing platforms (native platforms and meta-platforms) simultaneously. This is currently the case with most personal computers that are capable of running multiple OS.

3. Changing markets in operating systems

Figure 2 provides a classification of communication technologies according to the two most fundamental dimensions:

- analog vs. digital transmission of the communication signal
- mobile vs. fixed communication technology.

Both these dimensions identify alternative technological characteristics of the communication process. Yet the economic and social implications of the two dichotomies are very different.

First we have the analog-digital dichotomy. This dichotomy, dividing the upper section of the matrix from the bottom half of it, can be simply reinterpreted as a distinction in industrial terms (as a distinction between industries).

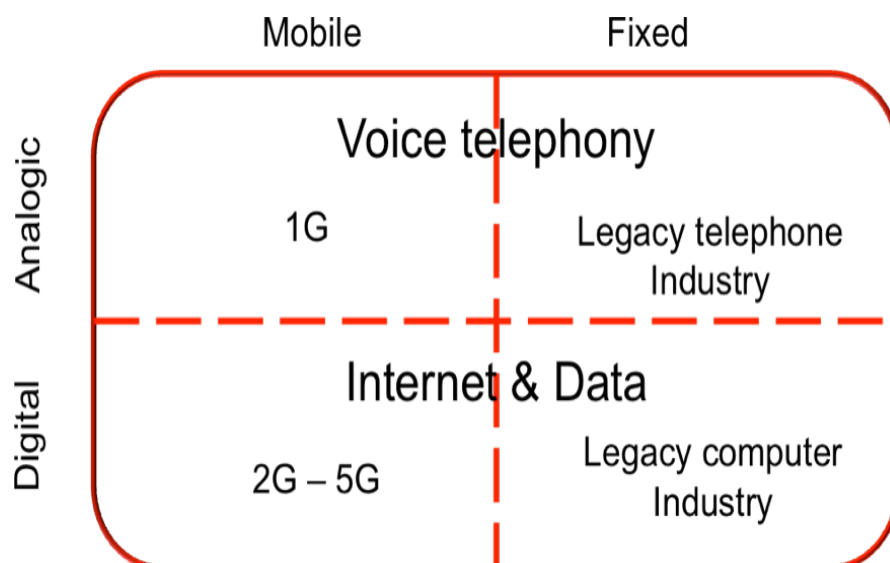


Figure 2. The mobile communication sector in context

The telephony industry has for one hundred years (from the late 1870s, until the early 1970s) provided analog transmission of communication signals, where these signals were nothing but one person's voice reaching the other person's hearing at a distant terminal. Here, the distinction between fixed and mobile technology is not very relevant. In both cases, we have the telephony industry.

The only relevant difference between the two "horizontal" categories is that while fixed voice communication in the telephone industry has mainly been (and sometimes remains) operated in analog terms (over copper wires), mobile telephony communication is not transmitted in analog form anymore and the technical legacy of analog telephone transmission is a very minor (and nearly irrelevant) one. The original 1G wireless telephone technology was the only analog communication technology in wireless communication. Since the advent of the 2G (GSM) standard in the early 1990s, mobile telephone communications have always been implemented in digital form.

As a result, the upper row of the matrix only covers fixed (legacy) telephone technology, with the upper-left quarter is now substantially nonexistent and only of historical interest. When the analog-digital dichotomy is considered, the row corresponding to the analog transmission of the communication corresponds to the (fixed) legacy telephone industry.

Things get a little bit less clear-cut when the digital transmission of signals is considered. In this case there is no single industry that can be unequivocally identified with the digital transmission of data. The internet and information industry rely on digital transmission and can offer communication services as well. This is how we describe the phenomena of convergence among several industries that was triggered by the digitalization of data transmission.

In this bottom row of the matrix it is still possible to identify specific industries. For instance, the bottom left section corresponds to mobile telephony, while the bottom right quarter corresponds to the (legacy) computer industry, where the machines are fixed on desktops. Yet, this industry (or industry segment) does not exhaust all the possible options, meaning that they do not unequivocally identify the category; while desktop computing should be located in the bottom-right quarter (digital + fixed communication technology), the reverse obviously does not hold, not all communication technologies belonging to that quarter can be defined as "computer industries". The same is true for the other bottom quarter of the matrix.

Unlike the analog section, it is in the digital hemisphere that the phenomenon of cross-industries where convergence is magnified and industries' boundaries become much less clear. Even more interesting than the previous "industry-based" classifications are the implications deriving from the switch from fixed to mobile and from analog to digital technology. It is over these implications that we can start to build an analytical framework that will help us to understand the novel nature of the issues that have to be addressed. Here we try to provide a very brief account of these two key implications.

If we consider the switch from analog to digital transmission of signals. The most relevant implication is the convergence of industrial sectors that have historically been well separated. This has mainly institutional and regulatory implications. From this convergence of the telephone, communication and information industries, a multiplicity of “second degree” implications follow. These implications derive from the fact that, while switching to the digital technology of transmission, the communication industry has adopted the standard protocols ruling the internet, and has therefore inherited some of its fundamental features and principles. For instance, one very important sub implication is represented by the specific technology of transmission of the signal: the switch from circuit-based to packet-based switching and routing technologies has implications for the performance of the overall system, and for the quality of the service provided. This is especially relevant when telephony is considered: under “best effort” transmission, which is the peculiar way in which a digital ecosystem operates, the quality of the communication is not guaranteed.

This change to packet-based transmission of the signal (which is important when it comes to regulate open access to the unbundled element of the network) mainly deals with the way in which the network is managed and organized. This is a direct effect of one of the most fundamental characteristics of the internet and of the way in which computer networks (as opposed to legacy telephone networks) work: the intelligence of the overall system. More generally the way in which it works (its performances and outputs), is not centralised in the system (or architecture) administrator (usually the network provider, or internet service provider) and is not located at the core of the network but at the edges of it, where final consumers (or end users) operate.

In effect, this “end-to-end” principle is what concerns us most here, and represents the most important implication of the digital convergence between information and communication sectors for our present purposes. Another way to interpret the principle is to conceive of it as an important switch from a (potentially) centralized management and organization of the production process, to a new decentralized way to organize and administer the operations of the entire networked system. Note that even the switch from a reserved channel, typical of the analog transmission of voice calls, to the “best effort” technology is inherited from the modus operandi of the internet and derives from the fact that in an end-to-end system it is not possible to guarantee the performances of the network centrally. Conversely, when a system operates via circuit-switched technology, as in the case of the legacy telephone industry, the network operator is able to control centrally and administer the functioning of its network, guaranteeing the communication between two end points in a centralized fashion.

A further important implication deriving from the digitalization of the signal (from circuit-switching to packet-switching technologies) is that information, data and signals in digital forms can now be stored, retrieved and used in a much easier, more efficient and more integrated way than ever before. This means that the source of

the flows of data and information, its usage and the access, and their appropriation and ownership suddenly become all very relevant topics. These issues were completely absent in the legacy (analog) telephone industry.

Hence the switch from the analog environment to the digital one has brought many new features into the picture. Among them, the particularly relevant aspect that we want to focus on is the new role of the end users. Intended as actors of the digital ecosystem, end users cease to be the standard “consumers” portrayed by economic theory and become simultaneously users as well as producers of valuable output. Figure 3 illustrates the conceptual change from the mono-directional approach adopted by economic theory, to the new bi-directional approach: final consumers are not just recipients of the “production flow”, but also an integral part of it. End users also insert new inputs into the production flow itself, making it bi-directional and blurring the lines between the role of producers and the role of purchasers or buyers.

In figure 3 we show that besides the usual top-down flows where services and goods flow from the producers to passive consumers (left), new bottom-up flows appear, where the end users are now active parts of the production process and the services now flow both ways: from the producers of services and goods to the end users and back.

The switch from fixed to mobile technology also had important implications for the communication sector, from both an analytical and conceptual point of view. This is especially true for the type and the patterns of usage of the handsets on the part of final users and, most importantly, for the new opportunities afforded by the ubiquitous and seamless environment. Thus, the switch to mobile technology affects especially the way in which users employ their devices and the type of data and information inserted into the network.

In effect, the switch to mobile magnifies the end-to-end principle of the internet, thus making the end users increasingly more relevant. Their increased relevance has to do with their role both as contributors and creators of new services, content and applications, and as providers of increasingly more valuable information. While digitalization and convergence represent the preliminary necessary conditions to include final users into the production process, mobile and ubiquitous communication increases their weight in the overall production and information process. The same holds for the gradual move towards decentralization (which is integral to the end-to-end philosophy): as more data, content, services and information are produced by the end users, the overall networked system can only move towards even more decentralized patterns of management and organization.

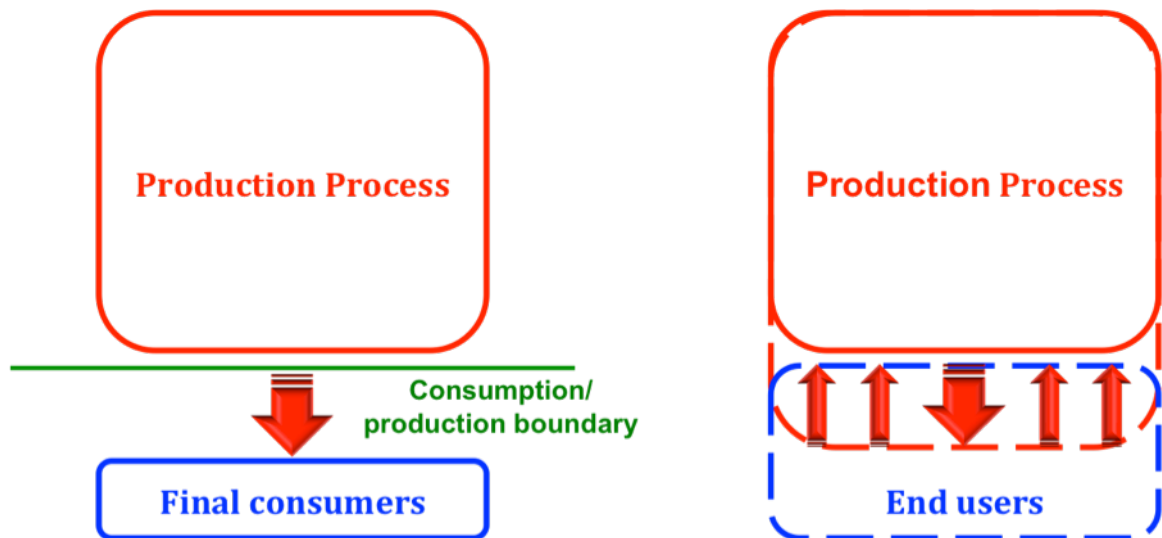


Figure 3. From the standard consumption-production economic paradigm (left), to the new mixed-paradigm of the digital communication environment.

What particularly interest us of this gradual move towards digital mobile communication are the following characteristics of the new environment:

- The increased relevance of users operating at the edges in the production process (as services, application and information providers);
- The increased (at least in theory) decentralization of the production of data, content and information;
- The increased importance of the edges of the ecosystem, at the expenses of the core: this is a decentralization process;
- The increased blurring of the boundaries between the final consumers' market and the production process, and the contamination of their respective roles in the economic landscape;
- The increased relevance of applications and information linked to (and exploiting) the seamless and ubiquitous nature of the new ecosystem.

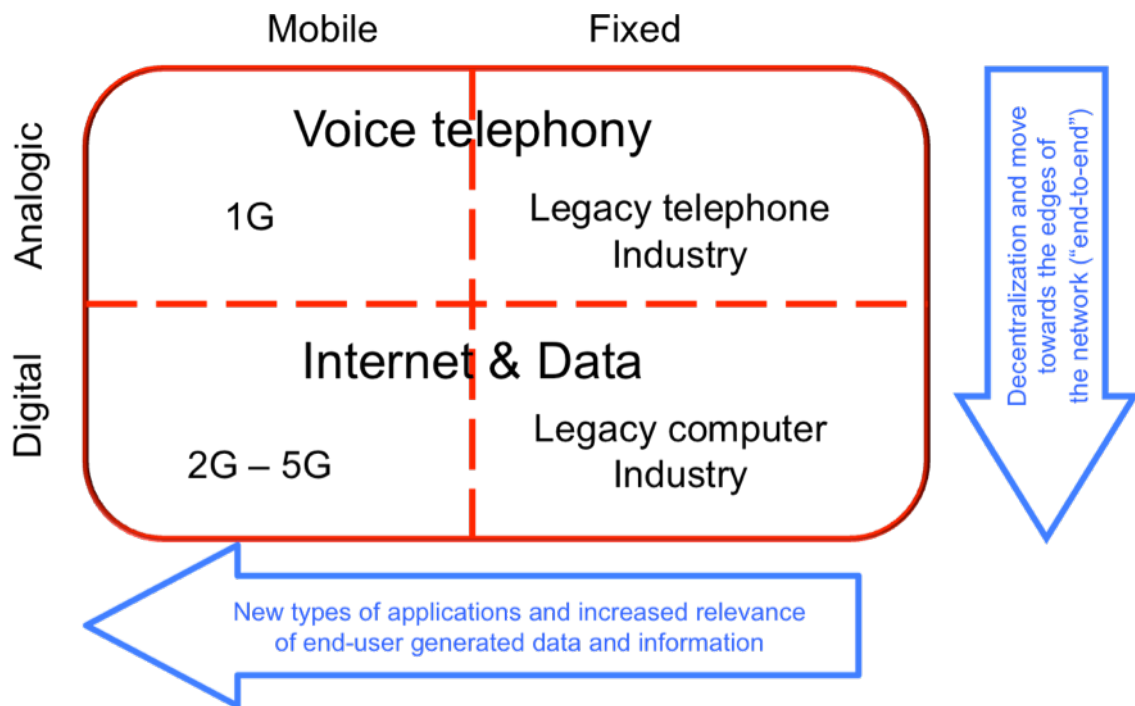


Figure 4. Some of the most fundamental implications of the switch from analogue to digital and from fixed to mobile communications

4. The new role of ownership and control of platforms

The previous characteristics are, in a sense, the ones that we would have in an “unperturbed environment”, meaning in an environment where actors passively accept the new tendencies and do not proactively react to them. In practice, the actors of the new digital ecosystem have already strategically reacted to these new characteristics of the ecosystem. It is now necessary to understand the new technological and economic factors driving actors’ responses, the new dynamic interactions that are being established among them, and the new equilibrium of the system.

To give just a flavour of the novelty of the situation faced by the analyst, consider the following: economic analysis in its normative interpretation (welfare economics) cannot provide satisfactory answers when consumers, besides consuming the purchased services and goods, also use them to increase their subjective utility. When consumers can directly influence their utility in a disjointed way from the act of consumption (as if they were also producers of their own utility, and not merely “consumers” in the strict meaning of the term), then welfare analysis and welfare categories (such as the one of consumer surplus) break down and are not valid measures of welfare anymore. Something else is then needed.

The role of OSs becomes fundamental: what is then the role played by OSs in the new digital and mobile environment? what are the technological and, especially, economic and policy implications of these changes?, to do this we need to reassess the two concepts of ownership and control in a way that becomes consistent with, and appropriate for, the features of the new context.

If we consider that this new environment is characterized by: (a) blurring boundaries between acts of consumption and production; and (b) reverse-flows of services and information from the (former) consumption side to the production side of the market. It then becomes apparent that the role of *control*, *access* and *ownership* of both tangible and intangible properties becomes crucial. If (a) all actors now participate to the production process with distinct roles (based on the usual consumer-producer dichotomy), and (b) what is purchased, used and produced by the final end-user at the edges can now be appropriated or used by the “service producers” at the core, then the once trivial, but now not-so trivial questions become: who owns what? Who controls what? OSs in particular, and digital platforms more generally, can play a key role in driving the forces that shape this new environment.

The new mobile communication industry has been greatly influenced by the computer industry. The top-down move (represented in figure 3) summarizes this heritage in terms of routing and switching technology (from circuit-based to packet-based), the location of the intelligence and control of the network (at the edges) and treatment of information (mainly generated by the end-users at the edges, and brought into the network from there). These are all changes that have been inherited from the computer industry and adapted to the new environment.

However not everything has been retained from the computer industry. Some features of the system have also been inherited from the telephone industry. In particular, the digital transmission of data has been implemented over the old telephone network: the modular architecture of the telephone network represents a key characteristic that has been retained by the new ecosystem.

This is an interesting starting point because we can have a much more detailed idea of how the “production process” looks: it can be seen as a series of interconnected modules that reflect the organization of the telephone network (in terms of last mile end-user interconnection, local exchange points, interconnection points, backhubs, backbones, and so on).

The literature is overwhelmed with studies on the technological, regulatory and economic implications of the application of the new digital services “on the top” of the pre-existing telephone network. Yet, the telephone network presented (and still presents, if we are merely talking of plain voice calls) a modular feature *at the core*. Considering that the only end-user device in the telephone industry is the telephone itself, this type of industry leaves little room for modularity at the edges of the network, beside the basic fact that final users have the freedom to choose which telephone to buy and to interconnect to the network (in the US, this is true since the Carterfone ruling of 1968 by the FCC). This, of course, is not an exclusive characteristic of the fixed telephone service: it also holds for plain mobile voice communication (such as the one in 1G, but also primitive communications occurring in 2G).

For the basic telephone environment, where the only service transmitted along the network was plain voice, the boundary line dividing the core of the network that deals with the provision of the service (generally speaking, the “production process”) from the edges of the network where the consumption of the service occurs, as represented in figure 2 above, then becomes as represented in figure 4 below.

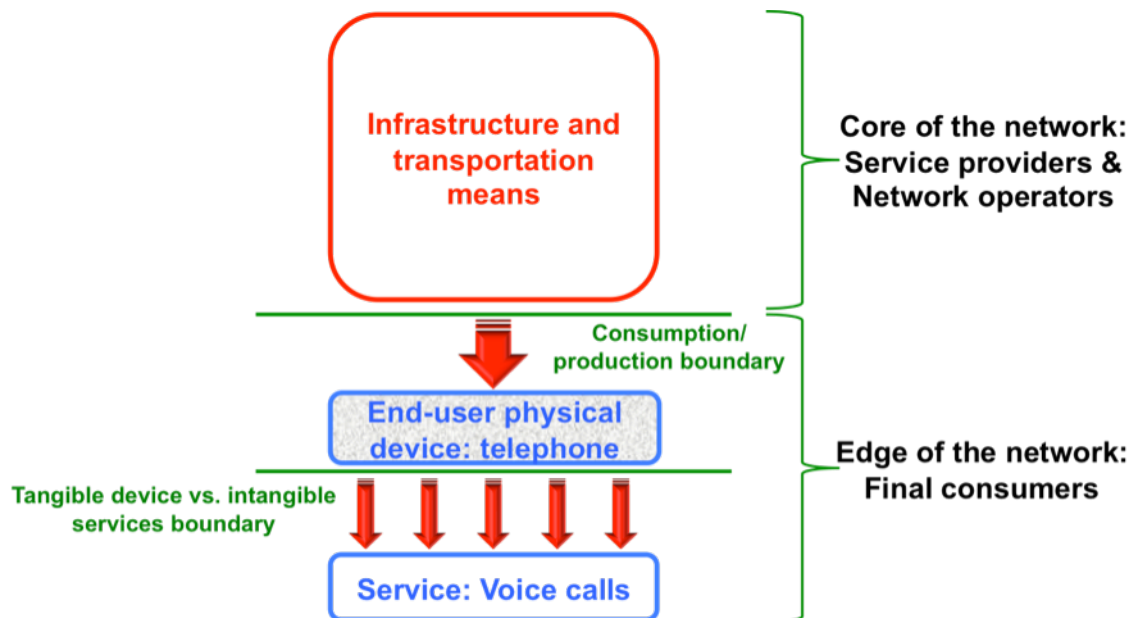


Figure 5. The legacy telephone industry: service-production and service-consumption in function of the core and the edges of the network

Figure 5 summarizes what has been discussed above with respect to the old characteristics of the “legacy” analog environment.

- First, there is a clear distinction between the edges of the network (where “consumption” happens) and the core of the network (where “service production” happens).
- Second, end users can only “consume voice calls”, but do not contribute by any means to the overall production process (the only contribution in terms of general value that a final consumer can provide is to increase the relative value of the network because of increasing returns in demand, provided that no interconnection between separate networks is mandated). This is the reason why no feedback flow is represented, going from the consumption field to the production field.
- Third, and linked to point two above, consumers remain consumers and do not become users. This means that there is no real added value for them in actively using the handset (the telephone), as the latter is only a passive medium through which telephone voice calls are placed and received. In other words, consumers increase their subjective utilities by consuming the

service “voice calls”, but not really by using the physical device “telephone” (stated differently, they only increase their utility by using the telephone device solely and exclusively because they are consuming voice calls, and for no other reason).

The legacy telephone system did not operate under the end-to-end principle, and the architecture of the system is overwhelmingly unbalanced towards the core, leaving little independence at the edges and delegating nearly nothing in terms of added value (added functionalities, services and performances). These considerations have important implications with respect to the conceptual categories of ownership and control.

In a “post-Caterphone” world, consumers own the telephone and can have more or less direct control over its usage (in the basic sense that they can decide when to place calls, and when to respond to calls). Yet they can do little more. Most importantly, they cannot decide how to use their own devices, in the sense that they cannot use the telephone as an intermediate medium in the production stage in order to go beyond the plain vanilla voice service, and escalate towards other, alternative, services and functionalities. With the advent of the DSL, this escalation in services (from voice calls to data transmission) becomes possible. Yet, the real escalation towards these “enhanced services” occurs at the core of the network (at the infrastructural level). At the consumer level, DSL services are guaranteed by a different device attached to the landline: the modem. In the case of telephony plus DSL (the standard configuration for decades), figure 5 would be modified, as represented in figure 6.

With a telephone plus modem configuration, the final consumer can consume both voice services and internet data services by using two different apparels: the telephone for the first type of service, the modem for the second type of service. Once again, in this 1990s world, final consumers cannot decide to use one device in order to perform a different type of service. Unless, of course, we add something else to the previous basic picture, such as an application installed on a computer. This would allow the final consumer to perform the same type of service that they could obtain by using the telephone through the modem. This would potentially push the final consumer to get rid of the telephone (now redundant) from the beginning.

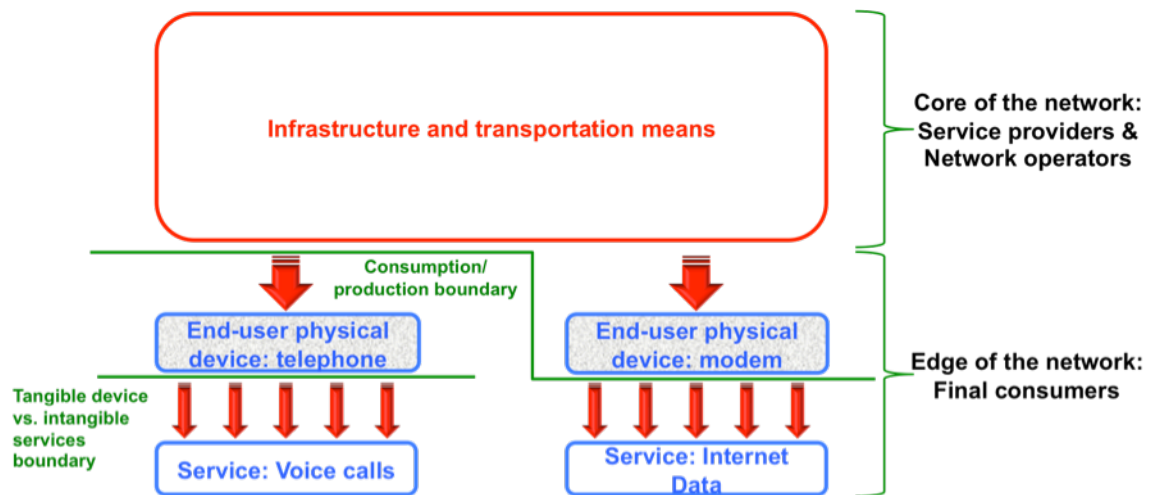


Figure 6. Voice call services and internet data services in the old legacy telephone ecosystem

Even in this seemingly simple and primitive world, things are more convoluted than that, and figure 4 should be amended. This is true for two important points to which we now turn. The following considerations will bring the discussion to the heart of the present argument.

5. Shifting the boundaries

The first thing to note is that differently from the telephone industry, modems in that configurations had to be leased by the final consumer. Thus, modems are not properly owned by the consumer: they are owned by the network operator (or internet service provider [ISP]). In other words, we are in a “pre-Caterphone” world with respect to the provision of digital data services by means of fixed connection.

This is the reason why the “production/consumption” boundary is a broken line that shifts downward as soon as we switch from voice services on the left, to internet data services on the right. Yet this means that, even though the modem is “located” in the final consumer’s premises, the latter does not really *own* the device. Thus, figure 6 should be amended in the following way, as represented in figure 7.

Figure 7 takes into consideration that the modem is an element of the production ecosystem and not of the consumption ecosystem, as it is only leased by the final consumer. The fact that the modem is not properly owned by the end consumer, but only leased, introduces the first complication into the analysis: even though the modem is located at the consumer’s premise, it actually represents the very last element of the production ecosystem. For this reason it is “absorbed” into the red boundaries of the “infrastructure and transportation means”. These means are owned by the services’ producers: the ISP (or network provider).

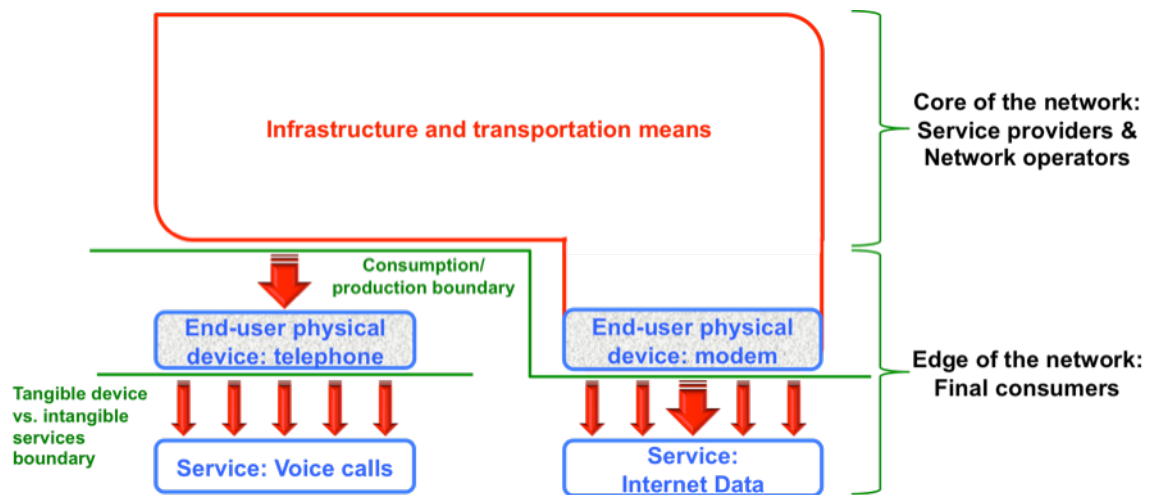


Figure 7. The new consumption/production boundary in the provision of internet data services

Note, moreover, that in contrast to what was happening in the voice service case, the extension of the production environment all the way down to the customer's premise generates that type of overlap between the consumption and production domains already introduced above (see figure 5 above for instance). With the lease of a physical medium the boundaries become blurred and less clear-cut. So much for the first remark (and the first amendment to the situation pictured by figure 5).

The assumption of a leased modem turns out to be quite useful not only for the present discussion. Rather, it constitutes a starting point for the second fundamental observation: the nature of the edges (the locus of consumption, or where the final customer effectively operates) when the service provided to the final customers is internet (data) and not telephony voice (by means of the standard telephone handset).

What emerges from figure 7 is that there is also a second overlap, beside the consumption-production overlap previously highlighted: the overlap or, more precisely, the coincidence, between two boundaries: the boundary separating the production from the consumption environment, and the boundary separating the physical element located in the customer's premise from the intangible element or, the services consumed by the final consumer.

This coincidence is represented in figure 4 by the shift of the thick red arrow downward: from the space above the tangible/intangible (or physical handset/services) boundary line to the space below that same boundary line. After all, this shift was driven by the fact that the actual market transactions (the provision of the internet services) between the producer (the service provider) and the customer do not occur at the edge between wire and modem, but really occur beyond the modem itself. This derives from a downward shift of the ownership domain itself, as previously outlined.

However, the final consumer does not need to own anything in order to surf the internet. In other words, there is no real ownership at the edges of the digital (internet) ecosystem. In order to benefit from an internet connection (in the “archaic” case considered by figures 4 and 5, as through a DSL), the final customer needs to use some additional device that can allow them to benefit from their digital connection. This device has to be interconnected to the modem, thus generating an additional layer of interconnection at the edges of the network (at the customer’s own domain) beyond those that are already present at the core of the network (the domain of the ISP). Moreover, to interconnect with a physical medium is not enough, some software or applications have to be installed on (thus interconnected with) the physical medium itself.

The response to this leads to a second amendment to our original benchmark (as expressed in figure 2): it is not true that the “physical device/intangible services” and the “core/edge” boundary lines have to coincide. Something else has to be added below the latter, and above the former. Operating systems are located precisely between these two boundaries. For this reason the two diving lines interact with the elements located between and at the edges of them.

The existing literature is not lacking analysis of the problem of modularity and interconnection among elements located on the customer’s side. What is lacking in the literature however is a better understanding of how interconnection and modularity interact with, and affect, the two boundaries between (a) the edge and core of the network; and (b) the services and physical platforms. The former dichotomy is about the issues of ownership (what is owned by whom), while the second dichotomy is about the issue of control (how someone is entitled to use something). The two boundary lines are in effect independent and disconnected. Having some control with respect to the use of the physical medium does not necessarily imply its ownership and *vice versa*. What can be done and what cannot be done with some physical platforms by the final user at the edge is a much more difficult issue to resolve than their ownership, although, clearly, there is a connection between the two.

Moreover, the picture is rendered even more complicated by a characteristic of the digital ecosystem: the fact that end users are integral to the production process, thus generating back-flows in service production from the edges to the core. So, the dynamic interactions between core and edges and ownership and control cannot be fully understood if the direction of the added-value services (whether it is from the core to the edges or vice versa) is not taken into account. Indeed, it might well be that it is the extent of reverse flows from the edges to the core that can have a role in shifting the relative positions of the two boundary lines. Note that all flows and linkages are bidirectional. This means that end users can be service producers, introducing value from the edges down to the core of the network. The opposite situation is also true.

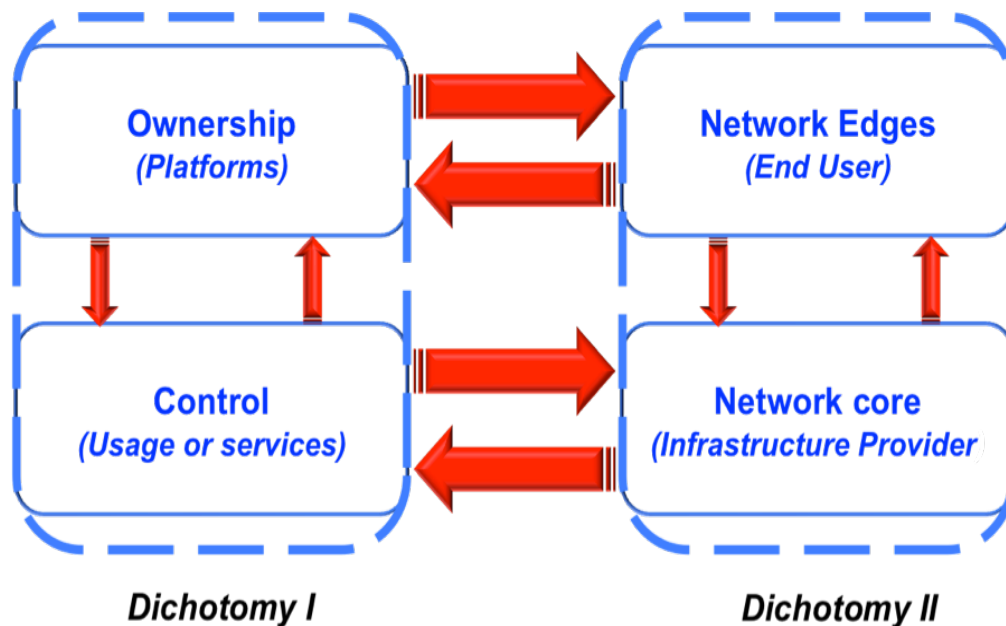


Figure 8 – Interacting boundaries (I: ownership of network elements vs. control of their services or functionalities & II: role of the edges vs. role of the core) and the direction of the services' flows

It is possible to see that the fundamental characteristics previously listed have now been taken into account. Namely:

- The complex interaction between edges and core, with unclear and blurred boundaries between what is part of the edges, and what is part of the core: this is the platform ownership issue;
- The complex interaction between what an end user can do with their platforms and mediums located at the edges, and what they are prohibited from doing (in “consumption” or for others “in production” –see the third point below): this is the control issue defining the platform-services boundary;
- The complex interaction between what is actually consumption and what is production, with unclear and mixed directions for the services that can climb up the production chain from the edges to the core. This is the decentralization issue linked to the end-to-end principle, defining the consumption-production boundary.

Thus, we have three key elements that dynamically interact between each other. These three elements define three moving boundaries (or control points):

1. The boundary defining ownership: who owns what and where. The “who” identifies the identity of the actor operating in the ecosystem (consumer or producer), the “what” identifies the nature of the object of interest (service or supporting platform), the “where” identifies the location in the network ecosystem (edges or core).

2. The boundary defining the relationship between the platform (tangible or intangible) and the services that can be obtained from its usage: who controls what and where;
3. The boundary separating consumption from production: who is selling something to whom and where.

The point to stress is that there is no clear pattern of the way in which these elements interact due to the fact that now the directions in which added-value services flow can be multiple: end users at the edges can just consume services while owning the platforms that they use, while at the same time they can also become dispersed producers of services and applications, while not owning (but, for instance, leasing) the relative supporting platforms. There can also be various combinations of these.

6. An overview of the proposed framework

The general intuition of the argument is as follows: in order to understand the dynamic interaction between ownership and control (platforms vs. services) on the one hand, and edges and core (customer's side vs. producers' side) on the other, and how the "direction" of value creation interact with them along the production chain, it is first convenient to distinguish between two types of modularity: modularity in production and modularity in consumption. While the former describes the architecture of the components in the core, the latter deals with the architecture of the components in the end user's domain (the edge).

To the eyes of those at the edge of the network, the modular architecture of the core of the network is a black box. The way in which the core of the network (the production environment) is organized reflects what here we call "*modularity in production*". This kind of modularity (dealing with the issues of interconnection, open access, and unbundling) is the object of interest of regulators, but not of the final users. At least it is not of interest to the end users directly. It can be of interest to the end user only indirectly, because of its implications for the second type of modularity: "*modularity in consumption*".

Modularity in production identifies the set of elements (modules) interconnected among each other (and compatible with each other) that are located in the core of the network, and are therefore within the producers' domain (ISP, VPN, network providers in general, and so on). The two characteristics of this type of modularity are:

- Producers own the elements (or modules);
- These elements are always inputs in the production process (or, they are part of the production process): they are used in order to deliver some type of service to the end users

Modularity in consumption identifies the set of elements (modules) interconnected among each other (and compatible with each other) that are located at the edges of the network, and are therefore located in the domain of the end user. This second type of modularity presents many more ambiguities than the previous one. For

instance, the question of who owns an antenna or an exchange point can be an ambiguous or complex one for a regulator, but it is certainly not an ambiguous one where the choice is between the end user and the producer. We cannot say much concerning ownership of the modules at the edge (ownership boundaries at the edge might be blurred and unclear). These elements are mainly outputs of a production process: they are sold to the final consumer or end user by whoever produces them.

The two definitions of modularity take the locations of the modules as the starting point (the two are defined as located in the core, or at the edges by definition). This means that one boundary line out of three is already addressed in the definition. Two boundaries are left to be defined in both cases. The difference between the two types of modularity is that while the former provides a clear picture of all the three boundaries, the latter does not solve all the boundary problems, and leaves one degree of freedom to the analysis.

More specifically, when dealing with modular elements in production we already know that: (a) they have to be owned by some producer, and (b) that they are part of the production process. Coupled with the fact that we already defined modularity in production as belonging to the core of the network, we can have an unambiguous idea of all three relevant boundaries, and of the directions of the added value in terms of services flow (from the core to the edge). Here, the only concerns that are still open, and should be addressed, are the competitive ones; these are the boundaries between competitors operating in the production process, at the core of the network. This is the task of standard regulatory and antitrust analysis.

However, when dealing with modularity in consumption, we know that these modules have to be located at the edges (the customers' premises) by definition and that therefore they must be located downstream from the production process, being output of the production process themselves. In other words, modules in this case are disposed of by the end user at their premise.

These aspects are not considered by standard microeconomic analysis in industrial organization (whether it is behavioral ex-post competition law or structural ex-ante regulatory economics). Industrial organization deals with the interactions among competitive producers strictly within the production process: the shifting boundaries under examination are defined among producers, rather than competitive interactions between producers and users when users can act as if they were integral parts of the production process: the boundaries between production and consumption are set and given and are not part of the economic inquiry.

Once the two typologies of modularity are clarified, it is now possible to go back to the original figures 8-9 above and to extend them to highlight the characteristics of the modular environment at the edge of the network or what has been called modularity in consumption. The new digital ecosystem is represented in figure 10. Here, the modular ecosystem is perceived by the final user in both the fixed and mobile communication technology can be conceived according to the standard

layered structure. That is, the set of four modules that form the modular system “in consumption” (at the edges) is characterized by the fact that these are those elements that the final end user can purchase on the market, and use at their premise, whether or not they own or control their functionalities.

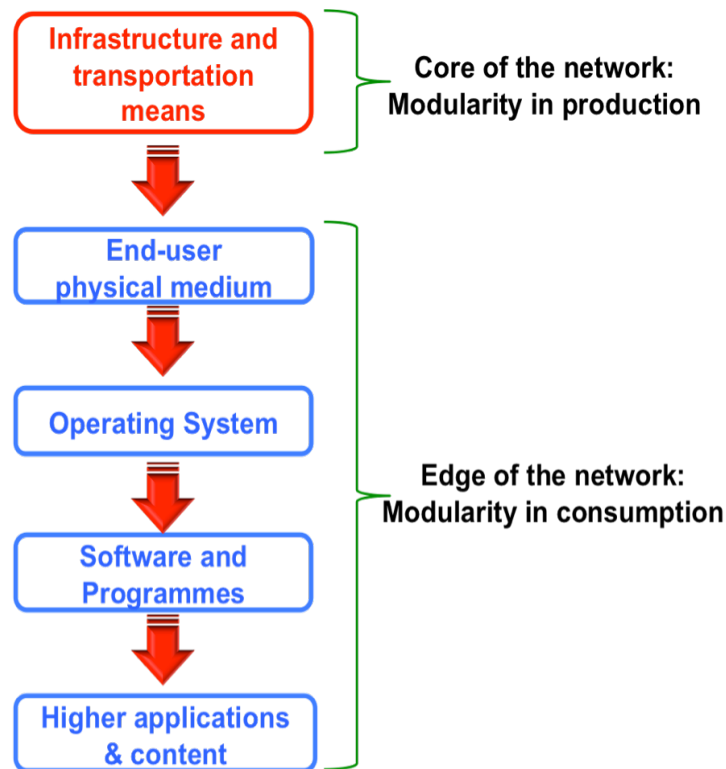


Figure 9. Modularity at the edges and modularity at the core: modules as perceived by the end user

Looking at figure 9, five basic layers, corresponding to the five fundamental building blocks allowing communication and transmission of data can be identified: the basic module corresponds to the transmission means, while the others identify to the various higher layers corresponding to, respectively, the physical device used for the communication, the operating system enabling the operation of the devices and all the higher functionalities of the device, the main software and programs allowing the basic functionalities of the device and enabling the fundamental connectivity functions, and the higher applications and content-based services. This layered-structure of modules is substantially identical to both fixed and mobile digital computer communication networks.

While both fixed and mobile digital computer communication technologies share the same typology of layers, the difference between the standard wire-based communication process and the mobile system is in the nature of the different modules, as are their respective roles within the ecosystem.

The fourth layer corresponds to software and programs enabling the functionalities and interconnectivity of the devices such as browsers, search engines, basic software such as word processing and document packages. For their increasingly expanding

role that social networks are acquiring in providing basic functionalities beside and in competition with other programs (mainly search engines), we also put social networks such as Facebook in this layer. At this layer, the difference between the fixed and the mobile environment is subtler and less apparent compared to the other layers. The main difference lies in the different functionalities, and in the different characteristics of the program whose aim is now performed over a mobile handset, and to enable new functionalities (and to support new apps) that exploit the new potentialities of the new ubiquitous and seamless environment.

Finally, in the upper layer (applications and content services in general) we find all other apps such as YouTube and Spotify used to download or stream content, or all other apps that enable a full exploitation of the opportunities opened to the digital mobile communication environment (from transferring money and pay, to maps, to fitness apps, and so on). This last layer is only loosely present in the standard wire-based ecosystem, and acquires full prominence and importance in a mobile environment.

The architectural configuration of the modular ecosystem at the edge must be linked with the three boundaries their location and behavior. There is a grey boundary line designating the two places defining the edge and the core of the network identified by the modularity of production or consumption. In the new digital communication environment it becomes much harder to clearly identify a priori:

- Where the end user ownership of the various modules is located vis-à-vis the producers' ownership of the same elements.
- Where the decoupling between the underlying platform supports is located vis-à-vis the functionality set (or service set) supported by it.
- Whether the service flows are all pointing down-ward (as in a standard setting where the end user at the edges is just consuming what is offered), or whether the end user is actually operating as a producer, thus using its modules and mediums in order to pipe further services (application, data or information) into the network in a decentralised way.

A fourth point resulting from the previous three is that we cannot know where this "reversed flow" of services starts or at which point of the modular environment at the edges the reversal of consumption into production can take place. One possible answer is that the OS can be considered as a "gatekeeper" of the entire system. Its functionalities and characteristics can represent a useful key to understand how all these independent variables dynamically interact in a coherent, and not causal, way. We have hereby shown how the type and the location of the reverse-flows in service creation can dynamically and endogenously affect the two boundary lines separating the location of ownership and control on the one hand, and tangible platform support and its functionalities (the services derived from it) on the other hand.

Figure 10 constitutes a graphical summary of all three dynamically interacting elements of the framework, adding the location of the services' back-flows.

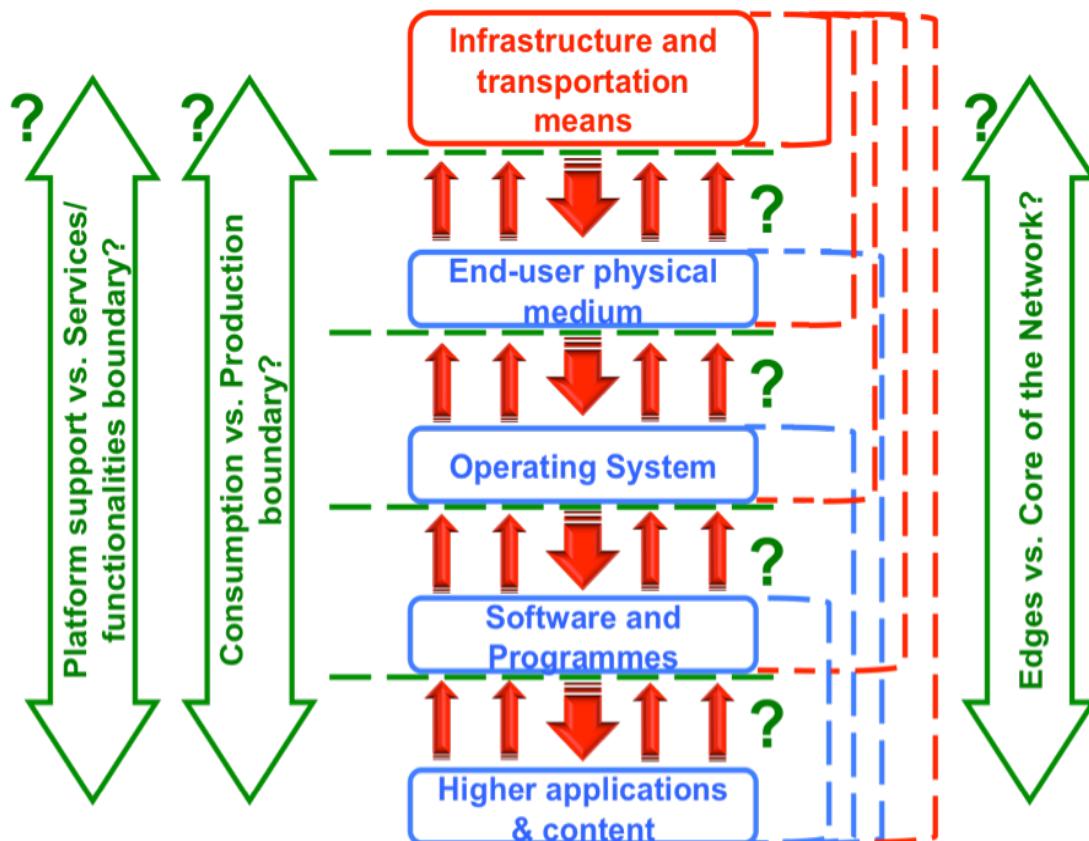


Figure 10. Modularity in consumption and the four interdependent moving boundaries: general overview.

7. Discussion

First and foremost, our approach addresses the implications for a policy analysis of blurred boundaries between the standard role of consumption and the standard role of production.

For the last half century, policy analysis has based its conclusions on standard industrial organization (IO) approaches. Basic economic concepts are of consumer and producer surpluses and social welfare, intended as some sum (or weighted average) of the two. For this approach to make sense, it is necessary to distinguish the role of consumers (the actors buying the services) from the role of producers (the actors selling the services). Social welfare and surpluses are computed in this way.

Yet in the new digital mobile environment, consumers do produce valuable services, or add value to the standard services sold to them. In particular, they generate information and data (as stated in section 3.3 above). These data become necessary for the actors operating in other layers of the production chain to add value to their services and products, and to generate brand-new services and applications.

Thus, a novel situation occurs: the overall welfare of the system cannot be subdivided into consumer surplus and producer surplus. Indeed, producers might

appropriate some part of the overall welfare by becoming “consumers” themselves of the information and data generated by the (previously-called) consumers.

Furthermore an immediate question arises at this point: are policy guidelines based on the standard IO analysis still valid and legitimate? Is the concept of surplus meaningful as soon as the “consumption” side of the ecosystem can add value and generate new surplus to the “production side” of it? To our knowledge, these are all novel and unanswered questions.

The second novel point derives from the previous one, and concerns the role of ownership (this constitutes the second key point highlighted in the discussion above). In the standard IO analysis, consumers purchase the final goods or services, and they are in complete control of their purchased inputs. As the final users can “consume” the purchased input according to their subjective and idiosyncratic “utility function”, the act of consumption itself becomes a legitimate concept in order to compute welfare and therefore to derive policy implications.

Yet, in the digital mobile industry most of the inputs used by the consumers are not really owned by the latter. Most of the inputs (intended in terms of both services and goods) used by the end user cannot be employed by the latter at will, according to their own “utility function”. The concept of ownership in law and economics is defined precisely by the fact that the “owner” has the right to exclude others from the use of its property, and can control the way in which others can restrain their usage of the latter.

The previous characteristics do not apply to the new industry: end users license, rather than own, the inputs (in terms of devices and services) that they use. Which policy implications (in welfare and surplus terms) should be derived from this radical change in the way in which ownership rights are allocated among producers and consumers? We are not aware of any study that has stressed the policy and economic implications of the blurred boundaries of ownership between consumers and producers.

The third point derives from the previous one and deals with the decoupling between services and physical supports, and therefore it deals more specifically with the issue of control (rather than ownership). The issue of control retraces standard issues covered by “vertical analysis” in competition policy (in terms of foreclosure, discrimination and fair usage). The literature in IO dealing with the problem of vertical restraints enquires about these aspects: how ownership in one layer of the chain affects the control of elements or modules in other layers of the vertical production chain, and therefore their usage.

This is a highly relevant topic in the modern digital mobile industry. Problems of compatibility among the various elements of the ecosystem are very real. These problems have been covered in the literature, but much less developed are the implications of compatibility for the definition of property rights, and for the appropriability of information, as discussed above. The OS layer can potentially

control which environment opens which application, and therefore define the ultimate ownership of the information and data generated over it.

If the final user cannot control the way in which its application can operate, or cannot control the way in which its applications will deal with the data and information generated, there might be a problem of vertical leverage of power, where the object of contention is not the “good-old” market dominance (leverage of market power), but the allocation of rights over the information and data generated.

The way in which vertical restraints shifts the rights of the actors along the chain is a problem much less developed in the literature and we are not aware of any work explicitly modelling and developing this issue.

8. Policy summary in the light of our analysis

Although our conceptual framework and analysis have been only tested in a few cases, we are convinced that some of our findings can help regulators do their job. Currently we have identified a few areas for policy impact:

i) Potential regulatory policy markets or law enforcers must consider how platform convergence affects the analysis of market power. In the current debate on telecommunications and internet access, the demand for internet access is a derived demand – derived from the benefit that consumers extract from consuming applications and content made available over the internet connection. This idea can be extended to operating systems; the usage of operating systems is also a derived demand, the benefit consumers extract from consuming applications within a platform and the context of the apps.

ii) Current operating systems developers when keeping control and ownership of a platform do slow down platform convergence. Policy regulators ought to aim to create favorable conditions for platform convergence since it has particular implications for new cross-device technologies. Competition is not limited to a particular device type, but rather can occur on multiple device types. Internet consumers are heterogeneous in their preferences for different applications and content and their willingness and ability to pay (in both cash and time). One of the benefits of the convergence of many different forms of applications and content into a single digital format has been the ability for these heterogeneous consumers to form their own customized ‘bundles’, this only can enhance competition within a platform.

iii) For regulators it ought to be a clear mandate to provide a regulatory environment where the goals of fostering and preserving interoperability between platforms is important rather than intra-platform conduct, given the reduced likelihood of lock-in. Digital platform consumers are not fixed in their preferences, because the range of applications and content from which they can select is constantly changing, leading to new opportunities for diversify and or bundle their applications to appeal consumers.

iv) In the face of both platform consumer and product heterogeneity, it is extremely difficult to define 'markets' that are amenable to analysis using classic competition law tools. It is even harder to undertake analysis when the actual and potential applications and content from which consumers construct their personalized choices are continually changing.

References

- Benkler, Yochai. "Coase's Penguin, Or, Linux and The Nature of the Firm." *The Yale Law Journal* 112, no. 3 (2002): 369–446.
- CB Insights. "Google Goofs: 23 Of The Company's Biggest Product Flops," 2016. <https://www.cbinsights.com/blog/google-product-flops/>.
- Cecere, Grazia, Nicoletta Corrocher, and Riccardo David Bataglia. "Innovation and Competition in the Smartphone Industry: Is There a Dominant Design?" *Telecommunications Policy* 39, no. 3–4 (2015): 162–75.
- Clark, David D., and KC Claffy. "An Inventory of Aspirations for the Internet's Future." San Diego, Ca: CAIDA, 2015. https://www.caida.org/publications/papers/2015/inventory_aspirations_internets_future/inventory_aspirations_internets_future.pdf.
- Davies, Ron. "Cloud Computing _ An Overview of Economic and Policy Issues." Brussels, Belgium: EPRS - European Parliamentary Research Service, 2016.
- De la Chapelle, Bertrand, and Paul Fehlinger. "Jurisdiction on the Internet: From Legal Arms Race to Transnational Cooperation." *Internet and Jurisdiction*, 2016.
- Eaton, Ben, S Elaluf-Calderwood, Carsten Sorensen, and Y Yoo. "Distributed Tuning of Boundary Resources: The Case Apple's iOS Service System." *Special Issue MISQ Journal* "Service Innovation in the Digital Age March, 39, no. 1 (2015): 217–43.
- Economides, Nicholas, and Steven C. Salop. "Competition and Integration Among Complements, and Network Market Structure." *Journal of Industrial Economics* 40, no. 1 (1992): 105–23.
- Economides, Nicholas, and Steven C. Salop. "Competition and Integration Among Complements, and Network Market Structure." *Journal of Industrial Economics* 40, no. 1 (1992): 105–23.
- Evans, David S., and Richard Schmalensee. "The Business That Platforms Are Actually Disrupting." Cambridge Mass.: Harvard Business School, 2016.
- Fleish, Elgar. "What Is the Internet of Things? An Economic Perspective." *Journal of Economics, Management and Financial Markets* 2, no. 5 (2010): 125–57.
- Frischmann, Brett M. "An Economic Theory of Infrastructure and Sustainable Infrastructure Commons." *Minnesota Law Review* 89 (2005): 917–1030.
- Gawer, Annabelle. *Platforms, Markets and Innovation*. Cheltenham: Edward Elgar, 2009.
- Hazlett, Thomas. *The Fallacy of Net Neutrality*. Encounter BroadSides. Virginia, USA: Encounter Books, 2011.
- Hern, Alex. "Google Reverses Decision to Ban Pixel Phone Resellers." *The Guardian* online, 2016. <https://www.theguardian.com/technology/2016/nov/18/google-reverses-decision-ban-pixel-phone-resellers>.
- Hern, Alex. "Pixel Phone Resellers Banned from Using Google Accounts." *The Guardian* online, 2016. https://www.theguardian.com/technology/2016/nov/17/google-suspends-customer-accounts-for-reselling-pixel-phones?CMP=fb_a-technology_b-gdntech.
- Howell, Bronwyn, and Petrus H. Potgieter. "Submission to the New Zealand Commerce Commission Re: Unresolved Issues: Vodafone Europe B.V. / Sky Network Television Limited." Wellington, New Zealand: Victoria University of Wellington and University of South Africa, 2016. English.
- Internet Society. "Global Internet Report 2016 - The Economics of Building Trust Online: Preventing Data Breaches." Washington D.C: Internet Society, 2016.
- Jansse, Marijn, and Anton Johan. "Challenges for Adopting Cloud-Based Software as a Service (SaaS) in the Public Sector," 2011.
- Kennedy, Joseph V. "Why Internet Platforms Don't Need Special Regulation." Washington D.C: ITIF - The Information Technology & Innovation Foundation, 2015.

- Killock, Jim. "Facebook Is Right to Sink Admiral's App." Open Rights Group, 2016. <https://www.openrightsgroup.org/blog/2016/facebook-is-right-to-sink-admirals-app>.
- Langlois, Richard. "The Corporation Is Not a Nexus of Contracts. It's an iPhone." Connecticut, USA: University of Connecticut, 2016.
- Lee, In, and Kyoochun Lee. "The Internet of Things (IoT): Applications, Investments, and Challenges for Enterprises." *Business Horizons* 58 (2015): 431–40.
- MacCormack, Alan, John Rusnak, and Carliss Y Baldwin,. "Exploring the Structure of Complex Software Designs: An Empirical Study of Open Source and Proprietary Code." *Management Science* 52, no. 7 (2006): 1015–30.
- Madison, Michael J. "Rights of Access and the Shape of the Internet." *Boston College Law Review* 44 (2003): 433–507.
- Manne, Geoffrey. "The EU's Android Antitrust Complaints Are Contrived." *Wire.com*, 2016. <https://www.wired.com/2016/11/eus-android-antitrust-complaints-contrived/>.
- Mossof, Adam. "Exclusion Ad Exclusive Use in Patent Law." *Harvard Journal of Law and Technology* 22, no. 2 (2009): 321–79.
- Mulligan, Catherine. "Mobile Network Platforms." In *The Communications Industry in the Era of Convergence*, edited by Catherine Mulligan, 171–209. London, UK: Routledge, 2011.
- OECD. "Machine-to-Machine Communications: Connecting Billions of Devices." OECD Digital Economy Papers. OECD Publishing, 2012. <http://dx.doi.org/10.1787/5k9gsh2gp043-en>.
- Page, Mark, Laurent Viviez, and Christophe Firth. "Internet Value Chain Economics: Gaining a Deeper Understanding of the Internet Economy." A.T.Kearney, 2010.
- Pasquale, Frank. "Beyond Innovation and Competition: The Need for Qualified Transparency in Internet Intermediaries." *Northwestern University School of Law* 104, no. 1 (2010): 105–74.
- Peltier, S. "Mergers and Acquisitions in the Media Industries: Were Failures Really Unforeseeable?" *Journal of Media Economics* 17, no. 4 (20014): 261–78.
- Rifkin, Jeremy. *The Zero Marginal Cost Society The Internet of Things, the Collaborative Commons, and the Eclipses of Capitalism*, 2014.
- Satell, Greg. "Platforms Are Eating The World." *Forbes.com*, 2016. <http://www.forbes.com/sites/gregsatell/2016/09/02/platforms-are-eating-the-world-3/#242df384652b>.
- Tilson, David, Carsten Sorensen, and Kalle Lyyntinen. "Change and Control of Paradoxes in Mobile Infrastructure: The Android and iOS Mobile Operating Systems Cases." Maui, Hawaii: IEEE Computer Society, 2012.
- Tseng, Fang-Mei, Ya-Lin Liu, and Hsiang-Hsun Wu. "Market Penetration among Competitive Innovation Products: The Case of the Smartphone Operating System." *Journal of Engineering and Technology Management* 32 (2014): 40–59.
- Vickers, John. "Competition Policy and Property Rights." Working paper. Oxford, UK: All Souls College, University of Oxford, 2009. http://www.economics.ox.ac.uk/materials/working_papers/paper436.pdf.
- Wagner, R. Polk. "Information Wants to Be Free: Intellectual Property and the Mythologies of Control." *Columbia Law Review* 103, no. 4 (2003): 995–1034.
- Weber, Rolf H., and Romana Weber. *Internet of Things - Legal Perspectives*. Springer Berlin Heidelberg, 2010
- West, Joel, and Michael Mace. "Browsing as the Killer App: Explaining the Rapid Success of Apple's iPhone." *Telecommunications Policy* 34 (2010): 270–86.
- Wirtz, B. *Media and Internet Management*. Gabler Verlag, 2011.
- World Development Report. "Digital Dividends." NYC, USA: World Bank, 2016.
- Yoo, Christopher, and Jean-Francois Blanchette. *Regulating the Cloud - Policy for Computing Infrastructure*. Massachusetts, USA: MIT Press, 2015. <https://mitpress.mit.edu/books/regulating-cloud>.
- Zelnick, Bob, and Eva Zelnick. *The Illusion of Net Neutrality: Political Alarmism, Regulatory Creep and the Real Threat to Internet Freedom*. 1st edition. Hoover Institution Press Publication - Book 633. Hoover Institution Press, 2013.