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FCJ-138 This is not a Bit-Pipe : A Political Economy of the Substrate Network.

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Introduction

In *The New Socialism: Global Collectivist Society is Coming Online*, editor of Wired magazine Kevin Kelly (2009) argues that the collaborative cultures emerging around web 2.0 platforms cultivate a "digital socialism", with broad political and economic implications for the producers of online culture. Kelly, alongside others, sees the digital commons as an arena for non-market collectivism that has the potential to extend influence to material circuits of production. Tracing a smooth trajectory from the publication of More's *Utopia* in 1516, through to the monopoly of YouTube at the time of publication, Kelly defines the core tenets of a networked utopia. This is premised on a decentralised architecture with the potential to scale the collective production of information, knowledge and culture, where open source software replaces communal tools and the 'desktop factory' succeeds the collective farm as the core space of common production. Applying the economic framework of socialism to online collaboration, Kelly's article is a classic symbol of the techno-ideology that surrounds the digital commons, a sign that the effusive rhetoric of the 'networked information economy' (Benkler, 2006) is alive and well in the public consciousness and has yet to reach its conclusion in the crisis of capital. This reflects this paper's core criticism of the ideology of free culture, specifically that its notion of "free" pays lip service to an imperial credo aligned more closely to the social factory than to the necessary apparatuses of an idealised peer-to-peer economy, rolling out a vista from Utopia to YouTube that wilfully glosses the conflicts inherent in immaterial labour (Lazzarato, 2005). [1] These conflicts concern the antagonisms between an informational space that circulates non-proprietary culture, and the very proprietary systems that constrain the digital commons. Too often, to paraphrase Galloway (2007), the modes of constraint operating through such a system are material, while liberation is semiotic. If Kelly's article demonstrates anything, therefore,

it is not the coming triumph of digital socialism, or the primacy of open source as a universal political model. Rather, it is always possible, and from the perspective of cognitive capitalism, profitable, to trade in the rhetoric of networked utopia, and in speaking, to obfuscate the really dominant mechanics embedded in the substrate of the digital commons, a power, as Hardt and Negri maintain (2009), embodied in property and fully supported by the law.

While Information and Communications Technology (ICT) is the spectre that haunts both utopian and critical accounts of the network economy, its physical concatenations are again and again rendered immaterial. The result is an ideology of free culture that champions decentralisation over all other considerations of the politics of network architecture, and a critical theory of immaterial production grounded in the labouring subject (Poster, 2005). Both perspectives elide a full consideration of the complex exchanges occurring between immaterial and material spheres of production. Networks are not only 'metaphorical tropes' (Galloway, 2004, p. xiii) for fluid forms of sociality, governance or commerce. To overlook the physicality of the network is to trade in a Church-Turing confidence in abstraction - the ascendancy of language, code and software over the material domain. [2] The digital commons is grounded in such materially entrenched sites of production. If the ideology of free culture is to progress beyond a pipe-dream, this project requires an active engagement with the politics of the substrate network.

The "network" of which we speak is comprised of contingent logical and physical strata: applications and content; the higher level protocols and services implemented in software, and the lower substrate network or "physical layer", comprising physical hardware such as channels, routers, storage and processing technologies and resources such as spectrum, bandwidth, real estate, man power and energy. Together these form the infrastructure on which content is produced, circulated and extracted. While there is a burgeoning acknowledgement of the politics of software, framing 'protocol' as a biopolitical architecture and locating the possibilities for 'exploit' through software related activism (Galloway, 2004; Galloway and Thacker, 2007), a consideration of the politics of physical media is largely absent from this discussion. More frequently this backbone is presented as the benign foundation on which a political architecture is implemented.

However, recent controversies highlighting the exercise of political sovereignty through communications infrastructure (El Amrani, 2011), and the various environmental, labouring and political conditions driving the information economy are gradually bringing the politics of the physical layer to the fore (Burrows, 2012; Greenpeace, 2012) It is becoming clear that we need a political economy that pays attention to how surplus accumulates at all layers

of the network: from content, through to logical processes, down to the substrate network, where immaterial and material circuits of production converge, and sometimes conflict. [3] This political economy is necessary to identify the modes of surplus extraction channelled through a proprietary network. Through such an analysis the substrate network ceases to be a benign apparatus and becomes instead a focal point at which the expropriation of the commons is not only visible, but increasingly precarious. The machinic underbelly of the network represents the limit point of abstraction, where the digital credo breaks down, and where the conflicts of cognitive capitalism are at their most explicit.

This paper explores the economic transformations to ICT business models, infrastructure and property relations emerging in tandem with an economy that places increasing emphasis on the circulation of user-generated content. Applying the newly invigorated theories of 'rent' to the shifting commons/property dialectics of the network economy (Harvey, 2001; Negri and Vercellone, 2007; Pasquinelli, 2008), we explore how various proprietary mechanisms facilitate the extraction of cognitive surplus. We then focus our attention on structural antagonisms emerging between competing modalities of rent and profit: where immaterial labour and tangible architectures intersect, diverge, and sometimes conflict. The diverse forms of surplus extraction across network layers are not always complementary, representative of a crisis of capital in which negotiations between fluid surplus and economic strictures threaten the consolidation of power in the substrate network. Political and economic control of infrastructure is changing as a result.

This paper provides a broad overview of the shifting terrain of physical media and as a consequence may seem to smooth many of the social and geographical particularities of information and communications technology in favour of overarching concerns: How is surplus from immaterial production channelled through a material substrate? What are the points of conflict and/or mutual enforcement between surplus extracted from infrastructure and surplus from cognitive capital? How are communications networks transforming in response to the fluid and fluctuating dynamics of the network economy? Finally, how might these transformations suggest opportunities for tactical engagement at the level of network infrastructure?

The Digital Commons

With the emergence of web 2.0 platforms that emphasise commons-based peer production and content-centric architectures, "free culture" emerges as a counter-capitalist ideology. This economic credo progresses and advances alongside the work of a new generation

of network culturists and has many advocates in both the core apparatuses of power and communities of digital activism (Pasquinelli, 2008). [4] Leveraging the flexibility of virtual commodities to cost free reproduction and distribution, these advocates present collaborative culture as a digitised gift economy (Barbrook, 1997, 1998) in which participants trade in social capital, self realisation, and various forms of non-market exchange. Advocates argue that the technological affordances of ICT networks facilitate the emergence of a non-proprietary information economy. These affordances include a consumer electronics culture that places the means of immaterial production in the hands of a majority, the primacy of distributed topologies and non-discriminatory protocols over traditional centralised communications, and a consequential shift from the audience as passive consumer, towards the ambiguous subjectivity of the 'produser' (Bruns, 2005) as an active agent in collaborative culture. Situated at the core of a global economy that places increasing importance on the circulation of knowledge, images and affects, network culture is thought to emerge in a favourable position to transform the surplus economy of material production. The pervasiveness of open source communities, user-generated content, DIY cultures and the peer-to-peer trafficking of rich media content over networks driven primarily by an economy of social capital, suggest for some a networked space emerging as a counterforce to capitalist accumulation (Lessig, 2004; Bruns, 2005; Benkler, 2006; Varnelis et al., 2008; Kelly, 2009). In such a framework, the digital commons is traditionally presented as a space unfettered by the constraints and exploitations that govern material production, conversely capable of exerting material influence through the economic centrality of immaterial production and the growing conflation of "real" and "virtual" spaces wrought by pervasive media.

In emphasising the primacy of immaterial culture, the utopian advocates of the digital commons gloss over its necessary symbiosis with, and subsumption into material capital, as a virtual space grounded in a proprietary and market-based economy. The digital commons is not external, but *central* to the mechanics of a capitalist regime that seeks new forms of valorisation for the owners of the Internet's core resources and infrastructure. A growing political vocabulary including "post-Fordism", the "communism of capital", "cognitive capitalism", "immaterial labour" and "biopolitical production" address these shifting relations between labour, property and capital at play in the digital commons. From the vantage of such criticism, the "network" ceases as a trope for counter-economic or autonomist culture and becomes an exemplar of corporate philosophy made visible through the recomposition of labour-capital relations around the social and technological labour of online communities. This marks a shift away from the labour-wage relations of the industrial economy, towards pervasive and precarious models of labour and a variety of automated apparatuses for the extraction of surplus (Virno, 2004, Marazzi, 2010). Similarly, it embodies transformations to the composition of productive capital towards a parasitic extraction of rent over common resources that were previously cast as external to the market. In the

network economy exemplified by web 2.0, value resides, therefore, not only in the exchange-value of communication resources and services, but in their extension through a common space of cognitive production. This includes immaterial surplus voluntarily produced on social networks, open platforms and cloud architectures and through the sifting, adjudication and dissemination of data by an underlying assemblage of decision engines, algorithms and network hyperlinks. These modes of immaterial surplus are channelled generously through a proprietary infrastructure. Indeed, it is largely through the exclusive control of such network resources that a profitable position can be established external to commons-based peer-production. We can therefore understand the idealised peer-to-peer economy as a gesture that is always subsumed before its politico-economic potential can be realised. Where innovations towards non-market and non-proprietary media practices possess the nascent potential to support an economy of free culture, these practices are subject to commercial constraints, the mechanisms of which can only be grasped through an engagement with all layers of the network. [5]

As an example we might consider the case of mobile and wireless networks. As computing migrates from the traditional desktop model, becoming nested in everyday contexts through mobile and increasingly pervasive networks, the advocates of free culture see these economies in turn progressing beyond a virtual domain, into 'hybrid space' (Kluitenberg et al., 2007) rendering the off-line world as a sort of 'Google-like utopia of universal digitisation'(Pasquinelli, 2008: 72). A number of recent wireless innovations including community Wi-Fi, mesh-networking initiatives, and forms of mobile peer-to-peer are lauded for their social and juridical implications. These include mobile citizenship, locative media cultures and various forms of pair-wise social exchange. A closer analysis of these mobile networks, however, quickly reveals the circulation of new forms of information capitalism, in which everyday networked activities produce surplus for the owners of the network's core infrastructure. These commodities include a whole range of user-generated content both consciously and unconsciously produced through demographic, psychographic, geographic, relational and even biometric data. This valuable data is used in turn to enhance, rationalise and personalise location-based marketing and advertising. The possibilities for such modes of extraction are dictated at every point by the material substrate of the network. Extraction takes place through proprietary terminal devices, network upload points and intelligent algorithms operating through applications, services and platforms. If a degree of openness is available at one level, the possibility of a mobile commons is still obstructed by various configurations of licensed spectrum, proprietary terminal devices and handsets, communication protocols, operating systems and core, backhaul and radio access infrastructure.

A Political Economy of the Substrate Network

An analysis of cognitive capitalism suggests that surplus extraction is negotiated laterally through a network oscillating between commons and proprietary apparatuses. Any engagement with the political economy of network cultures, therefore, requires an acknowledgement of the affordances and constraints operating across all layers of the network. Furthermore, it calls for a theoretical framework that teases out the antagonisms between various mechanisms, at turns proprietary and non-proprietary, immaterial and material. Such an analysis requires theoretical and political tools largely absent from the discourses of both advocates and critics of the digital commons. [6]

Beyond the merging of "virtual" and "real" domains through pervasive computing, there is no clear program for how a peer-to-peer economy might scale and advance beyond the confines of a virtual domain, uncoupling its circuits of production and exchange from the proprietary interests that underscore the substrate network. The technological infrastructure that sustains non-market exchange is absent in so far as it figures as a costly and complex assemblage of finite resources. Instead the digital gift economy is often framed as a universal political model. When open hardware and commons physical infrastructure *are* addressed, the irreconcilable nature of non-renewable and static resources to an ideology based on renewable and freely reproducible commodities is downplayed; immaterial and material products are conflated, and the proposal for a network 'free at all layers' (Benkler, 2006) follows a directive comparable to those emerging around the peer production of knowledge and culture.

These principles do not translate to the substrate network. In contrast to the widely lauded possibilities of free distribution of source code and APIs, material resources operate under different property relations. These resources continue to face tangible constraints to their ownership, scale and distribution. This concerns not only the physical injection of capital required to implement and scale a communal substrate, it is also subject to the impressive political constraints structuring the ownership and distribution of requisite real estate, electromagnetic spectrum, satellite technology, servers, bandwidth and energy. Despite the widely celebrated properties of decentralisation and non-discriminatory protocols, the network is substantiated in monopoly or oligopoly ownership, and a logic of scale and scarcity that prohibits access to all but the most powerful actors. As Galloway asserts 'ultimately the entire bundle (a primary object encapsulated within each successive protocol) is transported according to the rules of the only 'privileged' protocol, that of the physical media itself (fibre-optic cables, telephone lines, air waves etc.)' (Galloway, 2004:11).

Take, as one example, control of the electromagnetic radio spectrum. Spectrum provides the necessary frequency channels through which wireless signals propagate. Ownership has long been central to the valorisation of mobile and wireless networks, and continues to grow in economic importance alongside next generation IP networks such as 4G, LTE and LTE Advanced. This value is reflected in the exorbitant prices currently paid at auction for desirable frequency bands (Thomas, 2012). With the advent of radio transmissions at the turn of the twentieth century, spectrum was initially governed as a common resource and any party was free to broadcast. However, subsequent issues surrounding the management of interference lead to the gradual privatisation of the airwaves, first through state control and gradually through progressive deregulation, as desire for wireless bandwidth ceded to market forces. Today, access to electromagnetic spectrum is consolidated in a manner that favours exclusive usage rights by a few powerful incumbents. Licenses, granted by a national radio authority or federal commission, currently regulate the frequency at which a licence holder can transmit, the maximum signal strength permitted as an index of wave propagation, the geographic region over which the licence applies and the designated service provided by an operator. Spectrum licences, in turn, are traditionally partitioned to comprise not only discrete frequency channels or bands, but large geographic territories that bound regions or entire countries in some instances. As a result of such restrictions, the majority of spectrum is owned and controlled by powerful incumbents: commercial entities such as large scale mobile operators who can afford to pay for it, and privileged state controlled entities such as the military and public broadcasters.

Recently, the exponential demand for electromagnetic bandwidth, coupled with growing criticism of exclusive licensing, has fuelled debate about the possibility of dynamic spectrum access as a form of management. Dynamic spectrum access techniques pose a policy shift away from exclusive licensing of frequency bands towards a fluid negotiation of spectrum as a communal resource. While the scope of these transformations is beyond this particular paper, a range of regulations continue to frustrate the development of dynamic spectrum access networks, despite the ready availability of these techniques (Marcus, 2010).

Finally, a small amount of unlicensed or commons spectrum such as the 2.4 GHz band *does* exist, and has given rise to innovations such as Wi-Fi. However, this resource is still subject to both physical and policy limitations that restrict the scale of potentially “open” networks. Not only are unlicensed frequency bands a scarce commodity, in order to manage interference between multiple devices all transmitting within a small frequency range, commons bands are carefully governed by power-transmit rules that constrain wave propagation to within a limited radius. Consequentially, any network infrastructure that intends to provide coverage over a wide area requires access to spectrum that is licensed and auctioned on a scale that suits powerful commercial entities.

Spectrum policy is broadly emblematic of the prohibitions operating over substrate infrastructure. While "openness" and "sharing" as modalities of economic production are the watchwords of corporate web 2.0, this ethos rarely extends beyond the application layer. The physical layer, by contrast, consolidates the right to extract value from free culture, and continues to be associated with the rigid property rights of the Fordist economy. Such "choke points" are by no means exclusive to the physical layer. However, it is easier to exercise political and economic control over material and non-renewable entities than it is to implement strictures over the fluctuating and reproducible surplus of the digital commons. Google for example, a company whose revenue revolves around the attention economy, has multiplied its investment in infrastructures, from server farms and high speed networks, to energy (Fehrenbacher, 2010). Network surplus appears to operate through such contradictions, oscillating between a strategic access that favours audience circulation coupled with the exercise of economic barriers over communicative capacities through IP, digital rights management and other proprietary architectures.

The Becoming-Rent of Profit

The expropriation of the digital commons is not a smooth transaction, but constantly on the verge of crisis through antagonisms between the conflicting modalities of freely reproducible and finite resources, reflective of a lower level contradistinction between property and the commons. [11] This dialectic is characterised by what Post-Operaismo theorists define as the "becoming-rent of profit" (Negri and Vercellone, 2007). This provides a schema from which to advance a political economy of the substrate network.

Cognitive capitalism is characterised by the return and proliferation of forms of rent. Taking Napoleoni's definition, rent is the revenue procured through the exclusive ownership of some resource, such as land, where value is contingent on its availability with respect to demand (Vercellone, 2010). Until recently, rent was understood as a precapitalist legacy in which the rentier is cast as external to the production of value. This is in opposition to the tenets of productive capitalism, where the generation of profit is thought to require some direct intervention in the production process. Surplus accumulation is today characterised by a shift from productive capital to the growing conflation of rent and profit. Breaking down the Marxist distinctions between "rent" as value extracted through the exploitation of a static resource and "profit" defined as surplus accumulated through the production of mobile goods and services, the becoming-rent of profit sketches the fluctuating metrics of value emerging at the centre of a post-Fordist economy. Rent and profit become diffuse. In the current economy, the rent in question is not only an absolute rent applied to static property such as land or infrastructure, and profit does not refer exclusively to the active production of

material surplus. Instead, the vast majority of surplus in the digital domain is produced from the diffusion of cognitive capital through a proprietary apparatus external to production. David Harvey has described this process from the perspective of urban gentrification, whereby local cultural injections are leveraged against the financialisation of ground rent, escalating its real estate value (2001). Harvey's account is a description of how immaterial surplus, in the form of knowledge, social relations, images and affects are channelled through a material engine, producing surplus value for the owners of the metropolis. Value is grounded in a commons that is situated at the heart of a proprietary apparatus.

This model of surplus has particular resonances for information capital. Where Harvey's example concerns the role of real estate in the extraction of cultural symbolic capital, the credit title or exclusive ownership of an apparatus such as an algorithm, platform, server or communication channel is what enables the extraction of surplus from the digital commons. New forms of rent are increasingly generated from this property/commons dialectic, such as the rent of ICT companies over variable bandwidth, or the rent applied over the attention economy in web advertising (Pasquinelli, 2008: 96).

This is a highly complex and often conflictive process. Information exists not only as symbolic or cultural capital, but as an energetic quantity in the network. This produces a variety of different opportunities for the extraction of surplus from information, including both the content of a transmission and the infrastructure that makes such transmissions possible. A number of different commercial actors dominate the network space, therefore, including incumbent operators, internet service providers, network and consumer electronics vendors, software vendors, online software providers and content providers. These correspond to different revenue models and different conflations of material and immaterial surplus. A traditional system of accumulation over network infrastructure, for example, involves revenue extracted through a relatively static monopoly on the physical layer. The rent in question returns a differential that corresponds to capital invested in bandwidth and/or the inherent value of physical locations and local labour forces. Immaterial surplus figures in this economy insofar as it affects the supply and demand of communications resources such as spectrum.

More and more this relatively static form of rent over infrastructure is supplemented by systems incorporating the spatiotemporal vectors of what Pasquinelli refers to as "cognitive rent" (2008) into their value chain. Cognitive rent is surplus extracted from immaterial goods largely held and produced in common and is by nature more dynamic. In the becoming-rent of profit we can identify parasitic forms of surplus extraction that leverage or dynamically route around fixed property, establishing micromonopolies on fragile spaces. Value in the network progresses beyond "Infrastructure as a Service" (IaaS) towards the value of

productive spaces emerging across a wide range of intermediary platforms, social networks and mashup architectures. We witness this form of rent at play in the business model of a company such as Facebook, whose primary revenue is produced neither from the exclusive ownership of content, nor even the exclusive ownership of infrastructure, but through the parasitic extraction of value above and below these. In "Platform as a Service" (PaaS) or "Software as a Service" (SaaS), the productive capacity of immaterial surplus is channelled through proprietary resources held by internet service providers.

These new forms of rent are still dependent on material commodities, as substrate infrastructure at a physical layer or media content circulating at the application layer. We can identify in the becoming-rent of profit, therefore, a whole set of antagonisms between complementary and competing entities. This is a non-linear system. It traces a metastable economy that constantly negotiates the frictions between property versus the commons, immaterial versus material, in a cycle that threatens to exceed or undo the valorisation process. Hardt has described previous antagonisms in industrial capitalism between the model of the rentier and productive capitalism, in which the rent extracted from static commodities such as land competed with the mobility of commodities produced through labour, or between surplus produced through "rent" and "profit" (2010). If rent and profit are increasingly diffuse, Hardt, alongside theorists such as Vercellone (2010), locates similar antagonisms occurring between immaterial commodities - whose market flexibility elides strict proprietary logic - and the material resources that drive and expropriate the commons, subject to a logic of scarcity and costly reproduction. Such conditions have always existed, but are dramatically intensified through information capitalism. This in turn has implications for the organisation of proprietary infrastructure.

The expropriation of the digital commons always threatens to exhaust productivity, and similarly, the new modes of surplus extraction threaten the organisation of physical property. Often, the necessity of economic barriers that consolidate and exercise property rights are at odds with the growing centrality of the commons to information capitalism. These implications have already manifested for the owners of digital content, such as the media and entertainment industries, who are forced to radically alter their business models in response to the fluid and fluctuating metrics of the digital economy. But these conditions are prescient for the owners of network media also. While cognitive capitalism is progressively dependent on the exponential growth and availability of communications resources, it challenges the traditional owners of ICTs to extract a significant return from their investment in core infrastructure.

Transformations to Physical Infrastructure

In February 2010, The Economist reported that network traffic is exceeding the storage, computing and transmission capacities of available wireline infrastructure. Similar crises have been identified in the wireless sector, where exclusive usage licences over electromagnetic bandwidth are thought to precipitate an imminent "spectrum crunch", estimated to occur in late 2013 (Goldman, 2012). Here the subcutaneous workings of the digital commons are visible in the excesses of energy, capacity, labour and real estate required to support an information economy, manifested as pressure exerted by the circulation of digital content on a physical layer largely owned and maintained by ISPs. [7] In the new forms of rent underpinning cognitive capital, proprietary architectures are still essential to the digital commons. The monetisation of immaterial surplus depends on its extraction through techniques that rely heavily on material resources such as servers, storage facilities and large-scale processing capabilities. Any traffic in user-generated content, therefore, depends on the availability and development of high-speed quality infrastructure, manifesting where immaterial surplus exerts physical resources, operating over finite reserves of energy and physical space. However, as the requirement for a pervasive backbone grows exponentially with digital distribution, its value as a static resource is decreasing.

With the initial advance of the internet into a global marketplace in the 1990s, telecommunications providers were more than happy to provide the foundations for the World Wide Web. For these companies, additional revenues could be procured through legacy infrastructure without the need for significant additional investment (Leinwald, 2007). A service provider leveraged an existing monopoly over communications and a demonstrated ability to implement and scale a network in order to extract new forms of revenue. This value chain revolved around a traditional average revenue per user (ARPU) or pay-per-use model redolent of a flat rent on real estate. Following the Dot Com crash and the subsequent growth of web 2.0 ideologies, however, economic rationale shifted away from an emphasis on communications towards an emphasis on informational content (Dawson, 2011). The exponential growth of online traffic, both wireline and mobile, mean that network providers are now rolling out the next generation of networks to meet the demands of the modern internet (Alberti, 2010). These networks come at enormous cost. As the internet has scaled and pervaded everyday space, its ubiquity has fuelled an upward spiral of applications and services that require increasingly intensive use of its capabilities, a model that challenges incumbents to make any significant exploitation of their ownership (Allen, 2008). This presents as a demand for communications that is not economically justifiable through rent on infrastructure alone.

This structural contradiction is leading to a variety of significant innovations that challenge the normative distribution and deployment of traditionally monolithic resources. As infrastructure is imbued with cultural symbolic value (Harvey, 2001), the traditional property rights that structure the physical layer are in flux (Forde et al., 2011). In many cases we witness a transfer of power from operators with a legacy in telecommunications towards new actors consolidated in software and managed device platforms. As traditional operators struggle to adapt to cognitive capitalism, other powerful actors are multiplying their investment in infrastructure. Many of these have a legacy in software and content. Google, as previously discussed, has recently invested in network infrastructure including satellite, wireline and electromagnetic channels, cloud infrastructure, large scale ICT4D and even energy provision, becoming a registered electricity provider in 2010 (Fehrenbacher, 2010). Amazon too, with a legacy in content distribution, has recently emerged as a network provider, with services not only through their managed device platform, but through a range of cloud and hosting services such as EC2. These shifts imply new forms of management, new revenue models and new consolidation of network media. Specifically, such transformations sketch a transfer of control of infrastructure from traditional incumbents with a legacy in telecommunications towards software vendors and online software providers looking to consolidate their market position through investment in upstream traffic. In order to participate in this space, traditional Telco providers need to drastically reconfigure their industrial model towards the dynamic modes of appropriation redolent of cognitive capitalism.

This figures a growing emphasis in telecommunications on the importance and significance of services that expand technological rent over infrastructure towards increasingly dynamic modes of surplus extraction (Gardner, 2008; Slatnick, Parkins and Dheap, 2009; Telco 2.0, 2009; Keep, 2010). Traditional operators propose a growth in revenue through the construction of access-tiering, deep packet inspection and the imposition of trusted architectures at the behest of powerful actors such as the state, the media or entertainment industries (Slatnick, Parkins and Dheap, 2009). Another model advances a 'double-sided market' that extracts higher rent from profitable software and content vendors such as Google or Amazon (Kim, 2010). These proposals seek new ways to valorise property, consolidating exclusive ownership of the substrate through an oscillating technological rent over communications resources. Alternatively, network operators look to expand their portal capabilities to incorporate cultural symbolic capital as not only an 'over the top' activity, but as a key component in their value chain. In accordance with the economy of web 2.0, ICT companies in turn recognise the imperative to reorient the marketable internet away from general access and pay-per-use models towards dynamic service provision – a business model less concerned with the provision of hosting services than the permutation of users and valuable metadata (Gardner, 2008; Slatnick, Parkins and Dheap, 2009; Telco 2.0, 2009; Kelp, 2010).

The emerging importance of models such as "Cloud Computing" or "Managed Device Platforms" are key examples of this shift from static infrastructure towards dynamic and reconfigurable services. Network service provision shifts from an economic model based on the "dumb pipe" towards "service provision 2.0" (Leinwald, 2007), expanding beyond Infrastructure towards Software as a Service (SaaS), Platform as a Service (PaaS) and the dynamic extraction of cognitive capital through content produced across these proprietary architectures (Slatnick, Parkins and Dheap, 2009). This expands the operator's revenue from a static rent applied over basic connectivity and hosting facilities, to the provision of dynamic services for the assembly, storage and aggregation of digital content. We can understand this as a situation in which the traditional vectors of economic rent based primarily on substrate property are replaced by a model that applies cognitive rent over the immaterial surplus extracted through host infrastructure. Information ceases to be a drain on network resources, channelled 'over the top' of the substrate network. Instead, it is channelled through the foundations, dynamically leveraging the value of technological real-estate.

Furthermore, the traditional property rights that have long applied to the substrate network are in flux. Infrastructure is becoming fluid, moving away from industrial models towards flexible forms of accumulation. This can be demonstrated across wireline, cellular and wireless networks. In cognitive capitalism, proprietary logic does not necessarily disappear, but it is increasingly subject to the laws of diffusion (Rullani, 2004, Pasquinelli, 2008). If we understand the new forms of rent as a processual negotiation of the antagonisms emerging between immaterial and material surplus, the once highly structured and monolithic substrate network is increasingly fluid. The rigid economies of scale sought under Fordism have been countered by reconfigurable networks, the mobility of communication resources, and a growing centrality of sharing as a modality of economic production. Many of the proprietors of the network are moving towards modular architectures. This is manifested not only across mobile and ad hoc networks. It is also visible in the arrangement of technological elements that rapidly respond, not only to the behaviours of users, but to rapid fluctuations on the vectors of real estate, manual labour and processing power. Possibly the most illustrative example of this can be seen in recent patents for portable data centres, a trend that emerges alongside cloud computing. There is already a precedent for the geographic distribution of customer data storage and processing across multiple physical locations in server farms. Portable data centres extend this diffusion to the architecture itself, presenting a mobile and highly scalable storage infrastructure. Servers housed in arctic containers are circulated in response to wage/labour, energy, real estate, and ecological conditions (Barker, 2007). [8]

Already a key component of the digital commons, sharing as a modality of economic production has also grown in importance at the physical layer, as providers transfer, share, re-use, redistribute and otherwise deploy physical resources as needed (Bennis and Lilleberg,

2007; Agrawal, 2008; Arango and Kaponig, 2009; Wang, 2009; Forde Macaluso and Doyle, 2011). We might take the mobile network as an example: In early cellular networks, the carrier maintained exclusive ownership of all necessary resources, from electromagnetic spectrum through to antennae, base stations and the necessary real estate for their deployment. In emerging networks for 3G, 4G and LTE networks, previously centralised network assets are commonly distributed and owned by a variety of stake-holders (Forde, Macaluso and Doyle, 2011).[9] Architectures are emerging that virtualise the network [10], that support the concept of distributed or multiple points of connection, or that cede centralised control of transmissions from the mobile operator to the end user.

Recognising the importance of sharing of communicative capacity also has significant policy implications (Benkler, 2004). Transformations in electromagnetic spectrum policy provide further evidence of the distributed governance of infrastructure. Traditionally managed through a command and control model that bestows frequency bands to government agencies or large industry agents, the exponential demand for wireless connectivity has lead to widespread criticism of the exclusive usage model, previously outlined in this paper. The growing advocacy for unlicensed spectrum has progressed in recent years beyond a core group of commons idealists towards an industrial sector that understands sharing as a viable solution to resource scarcity. Recent technological innovations that propose dynamic spectrum access through cognitive radio or ultra wideband (UWB) transmission techniques are gaining precedence. [11] These technologies have the potential to transform how spectrum is traditionally distributed, challenging the economic barriers that until recently prevented public access to the airwaves.

Conclusion

Earlier in this paper, we noted that access and control of communications presents a point of opposition to open networks. Contrary to the fluid circulation of digital content, the structural ingredients of the physical network are not so easily distributed. Instead, the necessary flexibility of an economy based on commons-based peer production, such as that which characterises the digital network, is at odds with the Fordist models that, until recently, consolidated core infrastructure. This has posed a significant obstacle to collectives hoping to scale a network that is free at all layers.

Today, the technological dispositif is transforming in fundamental ways. It is as yet unclear whether this reorganisation spells a potential dissolution of corporate power or simply its recombination through more flexible channels. From one perspective these changes

depict a network inflected at all layers with the diagram of biopolitical production They also gesture to a decomposition of monolithic components, as rent destabilises property relations at the level of infrastructure. If a proprietary substrate underpins the expropriation of the digital commons, the current redistribution of property presents opportunities for structural exploit. Critically engaged during a stage of interpretative flexibility, alternative, commons or transient models of ownership might have positive implications for a networked information economy, emerging in a favourable position to disrupt the mechanisms of economic and political control channelled through its foundations.

Fully fleshed prescriptions are beyond the scope of this analysis, which is necessarily diagnostic. We can, however, identify possibilities for further areas of exploration, such as spectrum policy or future cellular networks, that draw on the conceptual framework of this paper.

Dialectical oppositions between licensed and unlicensed spectrum regimes have been discussed throughout this paper. Shifts toward dynamic spectrum access have significant implications as a disruptive technique. Cognitive radio - the signal processing and transmission techniques used for intelligent negotiation of available spectrum - presents the opportunity for unlicensed users to access spectrum that is owned by incumbents but substantially unutilised. This suggests a possible shift from inalienable property rights over a wireless channel towards a “spectrum commons”, where communicative capacities are distributed and partitioned as needed. Interestingly, the conceptual metaphor of “squatting” is sometimes used to describe the process of dynamic spectrum access, directly engaging the disruptive characteristics of the technique (Doyle, 2009). Dynamic spectrum access and/or an increase in unlicensed spectrum poses a direct sabotage on the rent applied over wireless infrastructure.

Another early possibility concerns the transfer of points of network control to end users. Moving from the centralised topology of traditional cellular networks, technologies such as the femtocell respond to network congestion by implementing miniature base station technologies for domestic use. [12] Users connect to the service provider’s cellular network over a personal network connection. Femtocells arguably cede aspects of network control to end users. The economic rationale behind this is controversial, based on the parasitic appropriation of user’s personal bandwidth capabilities to improve the range of a proprietary network. At the same time, it suggests a slackening of monopoly control, breaking a solid network into fluid components that might be accessed, shared, redistributed or otherwise modified.

Such proposals are tentative. When we encounter a new fluidity of property, it does not automatically follow that we encounter a diminution of corporate power, or that the consolidation of such power is necessarily "disorganised". Instead physical networks often cede to the diagram of the networked organisation (Rossiter, 2006), as the tensions between monopoly and competition, between centralisation and decentralisation or between commons and property are negotiated in fundamentally new ways. By this we understand, as Harvey does, that capitalism might become ever more tightly woven *through* dispersal, geographic mobility and flexible responses in labour and consumer markets, all accompanied by hefty doses of institutional, product and technological innovation (Harvey, 1987:159). Such flexibility is the operand of post-Fordism. An observation of early innovations suggest that the growing flexibility in material property that threatens the conglomerate is often countered with a stronger enforcement of symbolic and legislative apparatuses. These might take the form of stricter intellectual property regimes, or the enforcement of communications policies and protocols that seek to ensure network surplus does not escape circulation within the capitalist system.

The recent innovations in cognitive radio, for example, have been tempered by highly conservative regulations that seriously constrain unlicensed transmissions. Even though software-defined radios present the possibility for dynamic access to licensed spectrum, proposing a commons infrastructure managed as a public good, a number of early legislations concerning power transmit regulations and questions of "occupancy" continue to limit this access. [13] Femtocells, as discussed, form part of the new wave of components that allow for a scalable architecture, ceding control of core cellular infrastructure to the end-user. At the same time, recent proprietary legislation appears to ensure that these possibilities are suppressed in favour of the interests of powerful corporations. When the user places a call this is sent through the proxy servers of the ISP. The user is billed (again) despite the fact that the connection is facilitated through their own wireless infrastructure. Network carrier AT&T currently occupies a monopoly position in femtocell development in the United States. Recently, independent hardware providers such as Wilson Wireless wished to supply femtocells that are service neutral. The hardware specifications for both technologies are almost identical, but the third-party innovation sabotages the closed circuit necessary for the extraction of rent. As a result, and despite identical hardware specifications, AT&T successfully lobbied the FCC to disallow transmission licences by third party developers (AT&T, 2012).

It should be clear that the tensions between monopoly and competition, between centralisation and decentralisation or between commons and property are negotiated in fundamentally new ways. The material landscape of affordance and constraint are also shifting, and new forms of critical engagement are necessary. We need to be cognisant of the mechanisms through which value is produced within and across all layers of the network.

Not only do we wish to identify the techniques by which cognitive surplus is extracted through proprietary channels, but also to develop a political vocabulary that extends beyond the semiotic, towards the underlying material infrastructure of the network economy. If the ideology of free culture is to progress beyond a pipe dream, this requires an active engagement with such materially entrenched sites of production. This paper is not so much a program for future networked utopia, therefore, as an acknowledgement of the new sites of conflict through which alternative models of activism, policy or critical engineering might emerge. A conceptual framework is the first step in such an analysis.

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Notes

[1] The term 'Free Culture' can be traced to Lawrence Lessig's eponymous publication (2004). However, we locate the phrase 'the ideology of free culture' in the work of theorist Matteo Pasquinelli (2008, 2010). This phrase is used at times throughout this paper as an umbrella term for the broad rage of utopian ideologies surrounding "open source", the "networked information economy", "collaborative culture", and various non-market and non-proprietary practices emerging around the digital production and distribution of information, knowledge and culture.

[2] Friedrich Kittler writes about the Church Turing Hypothesis in his 1995 essay *There is no Software*. The Church Turing hypothesis is founded on the primacy of material abstraction through logical processes, advancing the claim that any programmable function can be performed by a computational machine. As a thesis therefore, it asserts the dominance of software over hardware.

[3] Political economy is characterized as the study of the interrelationship between the production and exchange of value and the distribution of power, agency and governance.

[4] The reader is referred to the work of Richard Barbrook (1997, 1998), Lawrence Lessig (2004), Howard Rheingold (2000, 2002), Douglas Rushoff (2002), Axel Bruns (2005) and Kazys Varnelis et al. (2008).

[5] Various technological models stratify the communications network as a means to delineate a series of interconnected protocols and standards governing its operation. Examples include the OSI model and the TCP/IP framework. In cultural theory, a triadic distinction is often made between content: the data, voice and rich media objects distributed by an underlying network infrastructure that is further divided along logical (software defined) and physical properties (concerning the connection of physical devices) (Benkler, 2006). While these models are conceptual frameworks and vary across disciplines, all utilise a tiered framework that extends downwards from an applications layer concerned with the provision of legible end-user content, through underlying logical protocols and standards concerned with applications presentations and transmissions, to a substrate network that defines the functional interoperability of hardware devices concerned with routing, transmitting and storing data channelled over a series of finite resources such as spectrum, bandwidth, data storage and power. Each layer is a co-dependent assemblage of functionalities. However, the layer model nonetheless visualises a hierarchy across both technological and cultural studies that places economic and cognitive emphasis on the higher applications layers, where content, and as a result, the consumers and producers of information, reside.

[6] With the emergence of software studies (Fuller, 2008) as a discrete field of research, coupled with the emergent discourses around "network cultures" (Terranova, 2004), a number of studies have traced the distribution of biopolitical agency through the algorithms, protocols and standards governing the logical layer of the network (Galloway, 2004, 2007; Galloway and Thacker, 2007; Mackenzie, 2006; Fuller et. al, 2008, Gillespie, 2010; Pasquinelli, 2010; Fuchs, 2011). This produces a counter-critique to the linear progressive celebration of decentralised topologies or non-discriminatory protocols favoured by the

advocates of free culture. Sites of analysis include immanent processes for the aggregation and analysis of habits or consumption and sociality, the politics of DRM and IP, through to the extraction of digital labour. Where these theorists trace the distribution of economic and political agency through software, forms of 'exploit' are in turn identified through software-defined activism (Galloway and Thacker, 2007). There is little discussion of the substrate network as part of this political assemblage, beyond analysis of the asymmetrical distribution of communications. It is presented as benign architecture, the "dumb pipe" over which an intelligent system is constructed (Fitchard, 2010).

[7] Avatars consume more energy than the average Brazilian (Carr, 2006; Pasquinelli, 2008). Data centres are predicted to be greater polluters than air traffic by 2020 (Lohr, 2008).

[8] Floor space is running out for most users today but use of IT is accelerating. Power is also becoming increasingly expensive and difficult to access. Also there are increasing carbon footprint awareness and the need to be energy efficient. To meet these challenges, container based centres are useful and will enable customers to expand their data centre capacity easily and quickly. Expect cost savings of 30-50% across various parameters such as real estate, construction, power, management and people costs. (The Hindu BusinessLine, 2011)

[9] Emerging Mobile Virtual Network operators (MVNOs) such as Tesco and Postfone, for example, own no physical infrastructure at all, and instead rent capacity in the form of bandwidth and billing services from traditional network operators (Forde, Macaluso and Doyle, 2011).

[10] Advances to the virtualisation of networks are also significant. While they contribute to the development and employments of low cost agnostic networks (Dawson, 2011), transferring intelligence to software architectures, they have also presented the open source community with possibilities to implement communications networks in environments and spaces where the prohibitive cost of core and backbone infrastructure was until recently a major barrier to implementation. For more see projects such as OpenBTS or Village Telco. http://openbts.sourceforge.net/, http://villagetelco.org/

[11] A cognitive radio is a radio that is aware of the environment in which it is operating, and that can reconfigure its operating parameters to best suit the environment. In the example in this paper – the radio would be able to sense or otherwise glean what frequencies bands are free, change its operating frequency to avail of an empty band, shape the wave it is transmitting to fit in the free band and support whatever application the user requires.

[12] A femtocell is a small cellular base station, typically designed for domestic use. It connects to the ISP network through the consumer's broadband connection. Femtocells are designed to extend and improve a service provider's coverage and capacity, especially indoors. [13] National Regulatory authorities are currently developing protocols for dynamic spectrum access in the frequency bands recently vacated by the transfer from analogue to digital television, known as TV White Space. The legislation includes a number of principles for negotiating access such as geolocation with database lookup – a technique that determines whether a frequency band is or is not currently occupied by the incumbent. Marcus (2010) has written about the politics of TV white space databases, arguing that these make use of a highly conservative wave propagation model that presents licensed spectrum as occupied, even though this is frequently not the case.

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