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How disruptive is 5G?

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A B S T R A C T

The hypothesis is put forward that, after three decades of stability, there is now the prospect of significant change in the vertical and horizontal structure of the mobile market place. On the supply side, significant factors are, first, the availability of a new and very powerful form of mobile connectivity in the shape of 5G, and second, software defined networking, which allows a single network to provide a variety of heterogeneous services or 'slices'. On the demand side, the digital transformation of the whole economy (and not just the communications sector) creates the need for diverse communications functions operating in a universe with a much wider set of digitally transformed services.

Mobile operators will find themselves contesting customer relationship with firms or other organisations providing these services in an integrated fashion, and thus risk replacing their direct link with end users with becoming the wholesale supplier of an expanded but 'commoditised' communications product. We may also observe fewer radio access networks; more competitive backhaul; and the (partial) vertical disintegration of mobile network operators. The regulatory changes implied may include heavier regulation of fewer RANs, and the need for market analyses to confront situations in which network operators sell more and more of their services to a variety of heterogeneous content and application providers – some of them exercising substantial levels of market power.

1. Introduction

The rather speculative and bald hypothesis of this article can be quickly stated. After three decades in which the competitive structure of the mobile industry has been largely unchanged - years in which four generations of mobile technology have glided past, and in which the traditional voice product has been supplemented and even overtaken by data services – there is now the prospect of significant change in the vertical and horizontal structure of the mobile sector.

This arises from a confluence of factors. On the supply side, there is the availability of a new and very powerful form of mobile connectivity in the shape of 5G. This will be based from the outset on software defined networking, which allows a single network to provide a variety of heterogeneous services or 'slices'. On the demand side, the digital transformation of the whole economy (and not just the communications sector) creates the need for diverse communications functions operating in an environment containing many more digitally transformed services. Mobile operators will find themselves contesting the customer relationship with respect to these services with firms or other organisations providing them in an integrated fashion, and thus risk replacing their direct link with end users with becoming the wholesale supplier of a 'commoditised' communication product, though they may continue directly to

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provide a limited general purpose connectivity function.

I conjecture that this may lead to a number of structural effects, including:

- fewer radio access networks (or RANs)
- more competitive backhaul and a more prominent role for content distribution networks (CDNs)
- the partial vertical disintegration of mobile phone companies
- the partial loss by mobile networks of their relationship with the end customer in communications services and their partial relegation to the subsidiary role of providing wholesale services to others providers.

The regulatory changes implied may include:

- heavier regulation of fewer RANs
- further competition in backhaul and core markets
- the need for market analyses to confront situations in which network operators sell more and more of their services to a variety of heterogeneous content and application providers, and fewer and fewer services to end users.

2. The unexpected structural stability of the mobile industry

The competitive structure of the mobile communications industry has been relatively unchanged over its lifetime. It continues to have a 'small numbers' market structure – the exact number of operators in each jurisdiction waxing and (in recent years) waning. Firms have generally persisted in the market, despite discrete merger and acquisition activity, and have seamlessly adapted to the successive generations of technology and to the transition for voice to voice and data services. New network entry has proved difficult in increasingly saturated markets, although a growing number of services are now contested between mobile network operators (MNOs) and OTTs (over the tops).

Mobile operators are much less regulated than fixed operators, despite concerns about explicit and tacit collusion. The burden of structural regulation falls on spectrum awards, which increasingly have involved interventions such as spectrum caps or set asides for new entrants, and merger control. With the exception of international roaming, retail price control is rarely employed, and wholesale price controls are largely confined to mobile voice termination.

A significant change relevant to the later discussion concerns increased infrastructure sharing by MNOs. This was first resisted by competition authorities, on the ground that it might lead to further unwanted or unlawful co-operation, but starting with towers and other passive assets it now sometimes extends to sharing electronic components and spectrum.

The smart phone-fuelled extension of the value chain over the past fifteen years into much heavier reliance on external rather than home-made content – video, social media, search etc. – has made a big difference, as has the presence in the market place of powerful new over the tops (OTTs), often in the form of multi-sided platforms like Facebook or Google. These both complement and compete with mobile network operators (MNOs). When they compete, pressure mounts on the regulator to level the playing field. Section 4 below also discusses the growth of content distribution networks (CDNs).

The UK provides a particularly strong example of the structural stability of the mobile industry, down to the level of individual firms. Thus the genealogy of the current four UK MNOs in 2018 is shown in box 1.

This shows dizzying changes in the ownership of operators - which involved both BT and Hutchison Whampoa starting up or buying and then selling one operator, before re-entering the market via another. But after the end of the mobile duopoly in 1993/94 (and ignoring start-up periods for the three later operators), the market shares of each of the four or five operators in existence fluctuated almost entirely in the 15–40% range. The combined share of MVNOs has never exceeded 15%. In short - a copy-book 'tight

Box 1

Ownership changes in the UK mobile market

EE (Everything Everywhere): acquired by BT in 2016, from a joint venture consummated in 2010 which combined France Telecom's Orange and Deutsche Telekom' T-Mobile; FT bought Orange in 2000 from Vodafone; which acquired it through its purchase in 2000 of Mannesmann; which bought it in 1999 from Hutchison Whampoa; which bought it from the original licensees (including British Aerospace); which launched its operations in 1993. Deutsche Telekom acquired and in 2002 rebranded as T-Mobile the mobile operator previously known as Mercury One-to-One, which started operations in 1994 under the ownership of Cable & Wireless.

O2: acquired by Telefonica from BT in 2006; BT was (with Vodafone) one of two inaugural cellular mobile licensees in 1984, trading under the name 'Cellnet' in a joint venture with Securicor, which sold its stake to BT in 1999; it sought unsuccessfully to merge with Three in 2016.

Three: owned by Hutchison Whampoa, Three entered the market as the fifth 3G licensee in 2003; it sought unsuccessfully to merge with O2 in 2016.

Vodafone UK: one of two inaugural cellular mobile operators in 1985, originally owned by Racal Electronics and subsequently floated off; no subsequent change in ownership.

oligopoly' of vertically integrated firms, latterly qualified by an increasing degree of network sharing.

3. The supply side: relevant aspects of 5G

Pinning down the nature of 5G really presents more serious difficulties than was the case with earlier generations. The key changes with 5G are increases in speed and decreases in latency. According to the European Commission, 4G data rates (which are typically shared across multiple users in the same cell) are about 500 Mb/s with evolution scenarios for going up to 3 Gb/s. Target applications for enhanced mobile broadband go up to aggregated speeds of 10 Gb/s – the 5G target set by the ITU.

These will require fibre-like radio access, probably using higher frequency bands than the sub-6 GHz in current use, and the use of beam–forming technologies.[2] It may be necessary to accommodate many simultaneous communications by densely-packed users or devices (up to 1 million per square km.) engaged in what has been christened massive machine-type communications, with large numbers of connected devices used in professional (eg health) or industrial applications or in smart cities, also involving large populations of sensors.

A second requirement for some uses is instant response time. Core 5G applications are said to require latency of the order of 1 ms, as compared with 10–20 ms provided by 4G. These are claimed to be needed for such purposes as health care, connected cars, and detection of faults in energy systems. These uses will combine 5G with mobile cloud technology to meet the more exacting end-to-end response times.

This will not happen overnight. As Lemstra (2018) observes, there are two different conceptions of 5G. Under the qualified version, 5G utilises its greater spectrum efficiency and lower costs to produce a cheaper and better version of 4G services – in particular enhanced mobile broadband. In the expansive version, not only the capacity but the scope of applications changes radically. Initially, the coverage of the qualified version will dominate that of the expansive version. The balance will then alter, at a different pace in different countries.

Two major consequences follow from these characteristics. The first is the need for more and different spectrum. Existing mobile spectrum lies uniformly below 6 GHz, and mostly below 3 GHz. Many (but not all) commentators believe it is running out.

Additionally, higher bands are more suited for high speed communications. The existence of high demand areas is likely to require spectrum regulators everywhere to make the necessary assignments, which may require appropriate adjustments to spectrum management practices (which are not discussed here). Because higher frequencies reduce transmission range, many more base stations may be required – a process which has been christened 'densification'.

A comparison of numbers of base stations in different countries shows the large difference between actual and projected cell sites per thousand population. The higher numbers in Asia than in Europe and the US are also demonstrated both in overall terms and in an even greater superiority of Asia in small cell sites. One explanation of these data is that it costs between ten and twenty times more to operate a site in the US and Europe than in Asia (New Street Research, 2016).[3] Thus the incremental costs of densification vary across the world, and this will affect mobile players' ability to compete in 5G. The existence of high demand areas is likely to require spectrum regulators everywhere to make the necessary assignments.

The argument has been made that in some countries the costs of installing small cells is so large, and the incremental revenues for so doing so small, that they are not a commercially viable proposition (Webb, 2017).

Conditions for the development of 5G in certain Asian countries, notably China, Korea and Japan, are propitious – according to New Street Research (2018) – from some or all of a range of factors including their endowment of dense networks, a strong early demand case, and an environment supported by a clear industrial policy.

In the US, the focus is on a laissez-faire approach, with early unrestricted spectrum awards (Pai, 2017). In Europe, a much more *dirigiste* approach is followed, with a 5G action plan heavily linked to the Digital Single Market (European Commission, 2016a).

There are further linked technical developments which have implications which go much wider than mobile networks. They have been trialled on 4G but are available for implementing on 5G from the outset.

The first is software defined networking (SDN).[4] This transfers the functionality needed in the network such as switching and handover from hardware to software, enabling variation in services and functionality to be made more readily.

The second is network function virtualisation (NFV). This involves implementing the functions of the communications infrastructure in software running on standard computing equipment, following the precedent of data centres, which have gone through a similar transformation. This reduces costs, and simplifies the addition of new services. The framework for these developments has been standardised by bodies such as ETSI. The thrust of this development in the mobile sector is to strengthen the trend towards the heterogeneity of network provision, the implications of which are discussed below.

The combination of these two advances allows network resources to be decentrally controlled by third parties which manage their own physical or virtual resources individually as needed to meet their own requirements. This is often described as 'network slicing'.

4. The demand side: digital transformation

At some risk of exaggeration, one might say that the only sector which has been subject to a complete and literal digital

[2] Beam-forming is already used in TD-LTE systems, which are seen as a stepping stone to 5G.
[3] The US and the EU are committed to dealing with this problem.
[4] These developments, and their implications, are discussed in Feasey (2016).

transformation is the communications sector. This has been accomplished by several means. Initially, the digitisation of the communications transport layer, beginning in the 1970s with digital core networks and completed later with the growth of IP networks and the progressive abandonment of analogue broadcasting. This has permitted the drastic changes which have occurred in the distribution of traditional cultural and media content, from music to news to books, accompanied by the development of completely new platform-based services including search and social media.

However other sectors lag behind – but perhaps not for long. This is recognised in studies by strategy consultants, too numerous to count, of the forthcoming global, regional or sectoral digital transformation. In a more general fashion the World Bank (2016) World Development Report *Digital Dividends* imaginatively analysed the impact of these processes with a focus on less developed countries.

A more important factor given our interest in structural disruptions is the nature of the demand. This takes us into the territory of 'verticals'-a term of art used in discussions of 5G to describe the emergence, as the process of digitisation of the economy develops, of tailored services relying on mobile (or fixed) connectivity and offered by private or public sector providers. Key and widely cited examples, in the provision of both public and private, and marketed and non-marketed services, are found in the following sectors: agriculture, automotive and transport, education, energy, financial services, financial services, government administration, health, manufacturing, and 'smart cities.'

A key feature of this extended list of services is that communication is not their raison d'être; nor is the communications component necessarily a major component of total costs. A plethora of organisations already provide the (largely) pre-digitalised service. There is thus room for conflict (or co-operation) over which organisation has the crucial contact with the end user, which in the case of marketed services is often a lucrative source of rents within the value chain, arising from consumer lack of engagement or bounded rationality – sometimes called a 'confusopoly', or a more traditional oligopoly.

A vivid example of these conflicts is currently on show in relation to connected cars, part of the 'automotive' vertical (Ramberg (2017) and Financial Times (2017)). Connected cars (to be distinguished from autonomous – 'driverless'-cars) are those that have access to the Internet and a variety of sensors, and are thus able to send and receive signals, sense the physical environment around them, and interact with other vehicles or entities.

In 2017, the forms of connectivity at issue include limited real-time car-to-car communications services (for example to avoid collisions by co-ordinated braking). In this regard the car makers favour a short range wifi Vehicle to Vehicle (V2V) technology requiring a dedicated spectrum band and a bespoke and comparatively readily constructed network. The telecoms companies' alternative is a long-range cellular network, the availability of which is dependent on the wider roll-out of 5G networks, where 5G may be a longer-lasting technology, capable of adapting to subsequent higher levels of automation. There are also solutions which involve interoperability between the two technologies. The European Commission is due to announce its formal decision on the choice of technology for the EU in 2018.

This is in addition to non time-sensitive applications ranging from performance updates and alerts on wear and tear of components, through advice on where to park or how to avoid congestion, to usage-based insurance charging.

The connected car market is fought over by automotive manufacturers/OEMs, tech companies and mobile operators – acting separately in a combination of modes. A key issue is whether the OEM has the car-owner interface, and organises connectivity, or whether the MNO takes the initiative of selling a monthly subscription service which gives the owner an interface with an aggregated set of connected car service providers.

It is foreseeable that the next stage – autonomous vehicles – will involve a much wider range of connectivity, including vehicle to vehicle and vehicle to environment. Given that autonomous vehicles are likely to come into operation in due course, and given the 'path dependence' of digitalisation within a sector, there is a lot to play for.

5. Structural implications for mobile

This section considers the structural implications of the expansive version of 5G described above. It first considers the narrower impact on the radio access network, backhaul, and core networks, then the broader effect of a much more extensive digital transformation.

The densification of the network will require, particularly in Europe and the US, investment in a substantial number of new small cells. In the US, the FCC has taken steps to reduce regulatory barriers to the installation of such cells, which are said to account for up to one third of their costs. New cells remain, however, a considerable financial burden.

One solution which has been raised in the US, at the National Security Council in the context of strategic global economic rivalry rather than that of communications regulation, is the co-ordination or even the financing of a monopoly 5G network by the US government (Axios, 2018). This would, it is argued, allow the speedy construction of a wide area densified network. The implementation of this solution seems a very long shot in the US, but the airing of the possibility is a recognition that, whereas hitherto mobile networks have been multiplied without incurring exorbitant cost, a fully densified mobile network will approximate more closely than its predecessors to the cost conditions of a 'natural monopoly'. It is also reported that, with government blessing, South Korean mobile operators and an internet service provider will share the costs and the use of 5G infrastructure deployment. The initiative is expected to generate savings of nearly USD 940 million over ten years (Telecompaper, 2018).

A less radical approach is to allow or encourage concentration or monopoly at the small cell level only, with points of interconnection with individual of MNOs at suitable locations.

Investment in 3G and 4G networks has already created a powerful stimulus, increasingly tolerated by competition authorities, towards the sharing of towers and other passive assets, and in some instances of active components. The installation of small cells imposes different challenges than traditional longer-range mobile base stations, but local planning type regulatory restrictions will continue to be a prominent factor in many jurisdictions.

These factors are likely to create further pressure to merge RANs. A balance may have to be struck between the cost savings which combinations of networks may lead to and the loss of competition and the closer regulation which such combinations would entail.

The numerous small cells will also require backhaul facilities, which will rely principally on fixed fibre networks; in countries with ubiquitous fixed networks these are already installed to provide fibre to the home (FTTH) or fibre to the node (FTTN) networks. Using these networks to provide additional backhaul from mobile cells could represent a major economy.

This economy of scope is not widely realised under 4G. In relation to the European Union, a BEREC report on fixed mobile convergence (BEREC, 2017) addressed the question of whether arrangements for mobile backhaul are currently satisfactory, and whether they will be so in the era of 5G. On the latter question it concluded that: 'According to most operators, fibre links will be necessary in order to meet the increasing data traffic over mobile networks and to meet the requirements in terms of latency, bandwidth and throughput in a 5G context', and that small cell backhaul solutions might differ from those for macro cell deployments. While spectrum-based solutions to the new challenges exist, 'the fibre optical solution is currently considered the most compelling as well as promising one' (BEREC, 2017, page 15). In this connection, New Street Research (2018, page 11) reports that in the US Sprint has agreed terms of access to the plant of two US cable operators to deploy its small cells at low incremental cost.

The proliferation of connections to small cells (where they have to be constructed *de novo*) therefore implies increased demand for backhaul, which might be met by new players and entail less self-supply by MNOs.

In relation to core networks too, the growth of demand for network services with different characteristics in terms of speed, latency etc. will increasingly be met by network slicing, possibly by means of the 'multi-tenancy' arrangement discussed below. But another important factor is the growth of content distribution networks or CDNs.

These involve the placing of major internet access points around the world and the use of a special routing code that redirects a Web page request to the closest server. When the Web user clicks on a URL which is content-delivery enabled, the content delivery network re-routes that user's request away from the site's originating server to a cache server closer to the user. The cache server determines what content in the request exists in the cache, serves that content, and retrieves any non-cached content from the originating server. Any new content is also cached locally. Other than faster loading times, the process is generally not transparent to the user, except that the URL served may be different from the one requested (Stocker, Smaragdakis, Lehr, & Bauer, 2017).

The significance of CDNs is demonstrated by the fact that 'with the emergence of popular video-streaming services that deliver Internet video to the TV and other device endpoints, CDNs have prevailed as a dominant method to deliver such content. Globally, 70 percent of all Internet traffic will cross CDNs by 2021, up from 52 percent in 2016. Globally, 77 percent of all Internet video traffic will cross CDNs by 2021, up from 67 percent in 2016' (Cisco Visual Networking Index (2017).

The principal effect is to make the backbone partly redundant, rather than to duplicate the local access network. But while some specialized firms are active in the CDN business, so are some content providers. Google for example is going into the business of constructing long-haul networks and laying undersea cables. With the growth of software defined networks, such content providers could seek access to a 'slice' of an ISP's network, thus creating a bespoke 'virtual' local access network and controlling acquiring end-to-end access to its customers. It could then 'zero-rate' its co-owned content to its heart's content.

This process would exemplify an extension of network slicing into a form of 'multi-tenancy', in which a network can provide a bespoke service to a wholesale customer offering a particular set of services related, for example, to the automotive or health sector. Following Lemstra (2018), the term virtual MNO is used to describe such provision. A UK precursor of this kind can be seen by the country's emergency services 'taking space' on a commercial MNO. Google Fi, a wifi-based network which uses contracts with MNOs to provide additional coverage, is another communications service example. Generalising these examples, a network becomes not a consumer service and not a single 'dumb' pipe, but a series of discrete 'made to order' pipes, probably sitting alongside the purely communications service for domestic customers which is recognisable today.

Putting these possible developments together, it is possible to envisage a future structure of the mobile sector in which.

At the horizontal level:

- RANs: fewer operators or more sharing of active or passive components especially in the large number of commercially marginal areas
- backhaul networks: more sharing between mobile and fixed networks, and additional competitors
- core networks: increasing use of CDNs
- content and applications: a) the proliferation of additional services in which the weight of communications services in value added is limited; b) increasing competition between MNOs and verticals in supplying these services to end users.

In relation to vertical integration:

- the possibility of stand-alone RANs; the untying of the current combined provision of the two functions by MNOs
- content and services: allowing increasingly variegated digital service providers to use network sharing and multi-tenancy to piece together their own virtual networks by buying wholesale inputs from network operators.

6. Regulatory implications

There is one respect in which the world projected here clearly risks generating additional regulatory problems, and that is the RAN, where pressures to consolidate look strong.

Recent mobile merger activity in Europe has focussed on four to three mergers between vertically integrated operators, although at the same time further entry has been accomplished in other countries, such as Australia, Singapore and Japan. The 'efficiency defence' for such mergers has been that the presence of the merged entity in the market place generates a faster roll-out of 4G networks and leads to a lower quality-adjusted price of services. That argument would no doubt be appealed to more strongly in the case of 5G densification – the costs of which are likely to be very large, although this will be accompanied by a much expanded demand for additional new network services required by the digital transformation, particularly in machine-type communications and high-speed and low latency applications.

It is difficult to predict how it will play out. But the European regulatory framework for electronic communications services, in the form of the projected European Electronic Communications Code due to be adopted in 2018 (European Commission, 2016b), with its revised focus on regulating oligopolies, should be able to cope with it, even it imposes more intrusive regulation of RANs in the form of mandated access and price regulation of the wholesale access services which content and application providers might seek.

This assessment might have to take place within the framework of a vertical structure containing more competitive and heterogeneous players in backhaul and core networks, generated by the changes foreshadowed above. This may lead to commercial pressures on existing mobile operators to separate themselves as a more specialized RAN operator.

Regulators might also be confronted with the prospect of mobile and fixed operators being relegated to a different role in parallel with their traditional one, as sellers of variegated network components to service providers which will own and control the relationship with the customer. This will require market analyses with a different focus and different levels of countervailing market power than are exhibited at present.

Finally, the developments described above are likely to require a review of current net neutrality regimes, to the extent that they outlaw the provision by ISPs of bespoke services to particular content and application providers.

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