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Virtualised and open RAN role in overhaul of mobile network sharing regulation in Europe for 5G rollout

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Abstract:

There is an investment gap to reach EU Digital Decade 2030 connectivity targets, requires from operators to provide full broadband fixed and mobile coverage. The reason is the lack of economies of scale, therefore return on investment often lags behind cost of capital in fragmented European national markets. Operators argue for market consolidation in form of horizontal merger, or at least market cooperation, like mobile network sharing.

Operators accept horizontal production agreement network sharing as a second best solution, however the bottleneck is the regulatory approval of urban full (active and passive) radio access network (RAN) sharing. Regulators still insist on parallel infrastructure-based competition instead of service-based competition on the same infrastructure. Virtualisation and open RAN technology enablers of mobile 5G transform the industry from closed to open market organisations, where multivendor upstream market competition also strengthen operator downstream and end-user retail market competitions.

The *research question* focused on how virtualized and open RAN with open market multivendor concept could mitigate regulatory anticompetitive concerns of network sharing in high density urban areas in end-user mobile services downstream market competition.

The *research methodology* built on qualitative techniques due to new technology development and limited available data. Exploratory analysis covers relevant academic, research institutes and consultancy papers. Secondary market insight data used for market development analysis.

The *main finding* is that, virtualised and open RAN intensifies competition, differentiation and innovation at vendor upstream market that has similar spillover effect to operator downstream and end-user retail markets. Due to network function virtualisation, software-based competition would permit higher economies of scale via network sharing at least in the physical hardware infrastructure segment, not only in passive, but also for active assets.

The *novelty* of the paper to focus on the bottleneck of mobile network sharing approval in case of urban active RAN sharing and connects with open RAN as a potential mitigation opportunity to resolve regulatory uncertainty and promote an issue of new regulatory guidance on mobile network sharing, helping both operators and customers, resulting a social welfare increase.

Keywords: network sharing, competition regulation, virtualisation, open RAN, 5G, cost efficiency, economies of scale

Disclaimer: This paper was written by Gábor Földes. Views are the author's own and do not necessarily represent the concluded position of Vodafone on particular matters.

1. Introduction

In 2021 the European Union launched the Digital Decade 2030 program, aiming to reach full fixed and mobile coverage in network rollout by Very-High Capacity Networks (VHCN). The parallel rollout requests enormous investments from Communication Service Providers (CSPs), measured by Capital Expenditure (CAPEX) intensity, which shows the annual reinvestment rate of revenues (CAPEX/Sales). The normal company total 10-15% range has increased to 15-20% already, and to cover estimated investment GAP to 2030 targets, only the network related investment part should reach 25% CAPEX/Sales ratio, doubling the current already enlarged investment bucket based on Analysys Mason, published by European Telecommunications Network Operators Association (ETNO). (ETNO, 2023) (Telefonica, 2023). The Analysys Mason report says that at the end of 2022, 55.6% of the European population had access to fixed FTTH networks, and 73% to mobile 5G. Compared to global peers, Europe remains behind as 5G population coverage reached 96% in the USA, 95% in South Korea, 90% in Japan and 86% in China. (ETNO, 2023)

The European telecommunication market is highly fragmented, therefore lacking of scale, due to not just the 27 members of the EU, but also much larger number of telecom groups operates, compared to other matured markets. Based on Analysys Mason report in US, South Korea and Japan the TOP3 operators share from total service revenue exceed 95%, comparing Europe total, where the TOP3 operators group share is below 50% and even TOP11 groups reaching 80%. (ETNO, 2022). Fragmented local markets also contribute to insufficient return on investments. Return on Capital Employed (RoCE) worsening, often lagging behind expected normal profit, Weighted Average Cost of Capital (WACC), driving one of the lowest EV/EBITDA (Enterprise Value / Earnings Before Interests, Taxes and Depreciation) valuations for telecoms, reaching only 5-8 times multiplier, compared to 10-20 in other industries (Arthur D. Little, 2021). Investors therefore undervalue the European telecom sector (Stoxx 600 Telecoms) compared to all industry European market (Stoxx 600) from 2017 continuously, while global telecommunication index (Stoxx global 1800 telecommunications) preserved its correlation with it. (ETNO, 2023)

Summing up from techno economics point of view in the European market there is lack of economies of scale, there are redundant parallel infrastructure assets with low utilisation and high spare capacity that not allows sufficient operational efficiency and cost savings, therefore investors in the stock market undervalue the industry. Operators are arguing for market consolidation (inland mergers, then cross borders), or at least market cooperation opportunities for telecommunication from sector and competition regulators. Regulatory bodies however prefers competition and innovation incentives over cost efficient solution that also contributed to current financial and economic landscape.

From technology aspects two parallel trends shape the market and operators' incentives. Firstly, normal technology lifecycle switch to 5G coupled with technology shift by network function virtualisation and open RAN that may transform from closed vendor lock-in to open multivendor model. Secondly, increasing mobile traffic by CAGR 18% till 2028 in Western Europe based on Ericsson Mobility report, requires high density macro and micro cell rollout. (Ericsson, 2022)

Altogether economic and technology trends call for an overhaul on mobile network sharing regulation, considering following reasons: (1) in mobile technology domain there is still demand for vertical passive and active sharing among Mobile Network Operators (MNO) for cost efficiency; (2) mobile passive networks assets in many cases carved out to MNO wing

captive TowerCOs or via horizontal merges sold to neutral infrastructure hosts; (3) RAN virtualisation and disaggregation ongoing with Hyperscalers and open RAN trials begun already, (4) in high density urban areas high band spectrums require micro cells deployment, where investment return excludes rational of parallel infrastructure rollout.

This paper is organized as follows: *Section 2* provides an overview of literature on horizontal mergers, horizontal production agreement network sharing, and infrastructure company TowerCOs with operator strategies, as well sector and competition regulatory assessment standpoints. *Section 3* describes the research methodology. *Section 4* qualitatively explores the virtualized and open RAN technology drivers and theoretical economic impacts, in particular to competition assessment framework, then introduces the current market and forecast trends on open RAN from operator side. *Section 5* summarizes the open RAN impact on network sharing, especially in urban areas. *Finally, Section 6* provides paper conclusions and recommendations for competition regulation based on the findings.

2. Literature review on mergers, network sharing and TowerCos

European national markets are hyper-fragmented compared to US or Asia, therefore operators claiming approval for market consolidation, like merger or at least cooperation, like mobile network sharing. The improvement of economies of scale is critical point to reach higher fixed and mobile network coverage. In this section I will describe in descending order market initiatives to improve cost efficiency from horizontal mergers via infrastructure sharing to infrastructure asset carve-out. The regulatory assessments undertaken by competition regulator National Competition Authorities (NCA), supported by sector regulator National Regulatory Authorities (NRA). At EU level the competition regulation led by European Commission Directorate General Competition (EC DG Competition) and sector regulation by Body of European Regulators for Electronic Communication (BEREC). In assessment process regulators have to balance among cost/investment efficiency (minimizing total cost), competition strengthening and incentives for innovation.

Competition is arguably most intense when the service providers own and operate separate facility networks, so regulators often restrict mergers and network sharing, or approve just as last-choice option, as threats to competition.

Economies of scale in the sector is required to avoid duplicated investments, spectrum inefficiencies and optimize asset usage. Capacity investments are designed to accommodate future traffic growth. Because traffic loads across locations and operators are subject to stochastic variation and are imperfectly correlated, sharing capacity among operators can reduce aggregate peak capacity investments, in particular in edge networks. Savings are direct results of reducing redundant infrastructure investment and potential to realize higher asset utilization when resources are shared. Building scale within national in-markets is a milestone for cross-border consolidation.

2.1. Horizontal mergers assessment

The key concern in horizontal merger related assessment, how to preserve competition. In telecommunication the most clear way, if *infrastructure-based competition* between parallel networks are maintained. The other option if *service-based competition* allowed, when

operators compete with their services on the same infrastructure that is the case in wholesale fixed access regulation or Mobile Virtual Network Operator (MVNO) services. In a merger approval process, when the number of independent parallel infrastructure owners are decreasing, a service-based competition can be imposed as a condition, like network open-up by compulsory reference offer to MNVOs.

On the other hand, from economics point of the forced infrastructure-based competition can be less cost efficient, as parallel infrastructure, often scarce capacity rolled-out and operated, where return on investment is in risk on the expected payback period by investors. The service-based competition with higher capacity utilisation and tenancy ratio are much more favoured by the stock markets.

In European merger approval till 2014 a service-based competition with network open-up commitment was a real alternative. In 2012-2014 period EC DG Competition cleared mobile mergers in Austria, Germany and Ireland, in all cases allowing for the reduction of independent mobile infrastructure operators from 4 to 3 in each national mobile market, but subject to a commitment to open-up for MVNOs to ensure greater competition. Even in case of Austria, Hutchinson3K had committed itself to bring in new MVNOs with a kind of access reference offer. In case of Germany and Ireland the MVNO commitments had been softer. (Genna, 2023)

From 2015 the assessment has changed generally, opposing merger proposals reducing the number of mobile operators from 4 to 3, which means that the infrastructure-based competition among independent networks is preferred over service-based competition. This was the case in United Kingdom and Denmark, where mergers could not be realized (in case Denmark stuck in and continued on horizontal production agreement, network sharing level). In case of Italy in 2016 the merger between Hutchinson3K and Wind was ultimately conditional on the sale of assets and spectrum in order to favour of market entry of French Iliad. The only exception was Holland the approval of the merger between T-Mobile and Tele2 in 2018, allowing the reduction of the Dutch mobile network operators from 4 to 3. (Genna, 2023)

Current cases are the announced Spanish merger between Orange and MasMovil that entered into in depth investigation by DG Competition and the non-EU UK also announced merger between Vodafone and Hutchinson3K. In both cases the number of independent infrastructure owner would decrease from 4 to 3.

DG Competition merger control in last years considering a mobile competition model based on the number of mobile networks, i.e. at least 4 in each national market in order maintain competition on infrastructure-based level. Nonetheless Groupe Speciale Mobile Association (GSMA) published a research on comparison of 4 and 3 player market from operators financial KPI and retail market price level aspects. The main finding was that on a 3 player market operators profitability (EBITDA/Sales margin) was higher, which incentivized them to reinvest more with higher CAPEX/Sales ratio. At retail market in a 3-player market operators did not have substantially higher Average Revenue Per User (ARPU) level and customers faced similar price level as on 4 player market. The non-financial network quality performance KPIs were also better for customers in a 3-player market by higher download speed and lower latency due to the higher CAPEX intensity (GSMA, 2020). Other research however shows that mobile monthly prices are in average 2-3 times lower in 4 MNO player market, than in a 3 player. (Rewheel, 2023)

The competition assessment of ongoing UK and Spanish cases will play a critical role how economies of scale can evolve with horizontal mergers and where the second best option, horizontal production agreement might gain more importance for operational efficiency.

2.2. Network sharing horizontal production agreement assessment

Mobile network sharing belongs to *horizontal production agreement* cases, as a softer form of horizontal mergers (Motta, 2003), in which only mobile network service technology production part at access segment will be common, while all other technology (eg. core network) and non-technology (eg.: marketing, sales, customer care, billing, strategy etc...) functions remain independent and competing. Network Sharing Agreements (NSA) are also a kind of *coopetition* (parallel cooperation and competition), where Mobile Network Operators (MNO) are cooperating in value-creation and competing diving it up parallel (Brandenburg - Nalebuff, 1997).

Mobile network sharing represents a *service-based competition*, as parallel infrastructure is consolidated and participating operators compete with their services on the common asset. So if competition regulators do not prefer approval of infrastructure competition eliminating horizontal mergers, might favour horizontal production agreements as it preserves independency in many corporate functions compared to full scale mergers. Purely in technology access network segment perspective, however network sharing has similar impact as merger, with a definite difference that two independent legal entities and brands using the common infrastructure, so the service-based competition is inherently given.

Scope of mobile network sharing

This paper focuses on the mobile network segment, either the mobile part of integrated fixed and mobile operators or the solely network of a pure mobile operator. The operators will be called Mobile Network Operator (MNO) for both cases. The mobile infrastructure main elements are Radio Access Network (RAN), Transmission (TRM) and Core network domains. The mobile infrastructure sharing covers mainly the mobile “last mile” RAN, physically the mobile basestations, towers. RAN contains *passive*, non e-electronic elements, like towers and site compounds and *active*, electronic elements, which covers all electronic communication parts of the sites. The main types of Network Sharing Agreements (NSA) covers either the smaller, passive scope (*Passive sharing*) or the higher scope, additionally the active sharing top on passive sharing (*Active Sharing*). The normal Active Sharing called Multi Operator RAN (MORAN), while active sharing extended to spectrum sharing also, called Multi Operator Core Network (MOCN). These sharings cover the access transmission network parts also. In special cases the core network is shared, but it would be a full network consolidation, a merger in network function. In vast majority of the cases core network is out of sharing scope, as core network is responsible for the network capabilities (eg.: products, service, billing capabilities etc) that differentiate the networks what retail end-users can perceive even in shared networks. Several further classification exists for network sharing types in dimensions of technology generation, spectrum, area, market context, operational model, etc described in previous paper (Földes, 2023).

Economies of scale form Mobile Network Sharing

Improve asset utilisation is the main incentive of operators, who are not allowed to merge or just want to benefit from cooperation in network rollout and operation in certain dimensions. Increased efficiency measured by OPEX and CAPEX savings.

Several academic empirical researches available on determining savings potential. Oughton published a research on cost, coverage implication of 5G rollout covering Britain (Oughton & Frias, 2018). Oughton participated in another study that assess 5G infrastructure sharing business models in rural areas and identified savings potential as follows: 10-20% for passive sharing, 20-35% for active sharing, and 35-50% for 5G neutral host networks compared to baseline no sharing case (Koratagere Anantha Kumar & Oughton, 2022). Rendon Schneir performed a cost assessment of multi-tenancy for a 5G broadband network in a dense urban area (part of London). The finding was that there was a 13.6% reduction at Total Cost of Ownership (TCO) level for the case of two typical legacy MNOs migrating to a multi-tenant strategy. The CAPEX and OPEX cost reductions were 15.7% and 12.9%. (Rendon Schneir *et al.*, 2019).

Telecommunication advisories also published savings potential of network sharing. WIK consultant examined the RAN sharing operational efficiency for the NRA of Switzerland, and identified up to 40% a saving range. (WIK-Consult, 2016). Analysys Mason research data was referred by Telefonica Spanish incumbent operator that MORAN active sharing has 30-40%, while MOCN active sharing has 40-50% savings potential (Telefonica, 2019). Deloitte experienced savings range 16-35% for passive sharing, 25-35% for MORAN active sharing and 30-45% for MOCN active sharing.

European regulator BEREC also reported that cost-savings from different types of sharing agreements yielded reductions in CAPEX of 16–45%, and OPEX of 16–35%. (BEREC, 2018)

All these data clearly state that blended CAPEX & OPEX savings may exceed one third of the cost baseline, which is remarkable efficiency improvement.

Competition assessment of network sharing from academic point of view

A large and growing body of literature has investigated the competition policy related assessment of mobile network sharing, discussed in depth in previous paper (Földes, 2022a) and key-findings listed here.

Bourreau in frame of Centre on Regulation in Europe (CERRE) publication provided the most comprehensive assessment framework on procompetitive, anticompetitive aspects and gave recommendation how to perform network sharing in compliance with competition policy to get approval. Bourreau's overall conclusion is that network sharing leads to coordination of investment, but not in pricing decisions, therefore it should be seen more positively than mergers, since there is no harmful price coordination. (Bourreau *et al.*, 2020a)

Pápai identified the following three layers, as production layer, wholesale layer and retail layer. Production layer, the network technology market is a functional upstream market and the retail market is a downstream market. Mobile Network Sharing Agreements impact the production upstream market only. Pápai also added that only RAN production part of network technology upstream market is affected, the Core part remains fully independent that allows MNOs to

determine and differentiate their own product, service and pricing capabilities (Pápai et al., 2020a).

Motta and Tarantino performed a theoretical model to study the impact of a network sharing agreement between two (mobile) operators on prices and investment in an oligopolistic mobile market. They analysed the incentives to invest in cost-reducing innovations: coordinate their investment while competing in prices. They found that without merger's investment synergies, a horizontal merger reduces consumer welfare. If synergies are sufficiently large, consumers benefit, as network sharing agreement leads to lower prices and higher investment, and therefore increases consumer surplus. (Motta & Tarantino, 2021)

Maier-Rigaud first outlined a theoretical argumentation, in which distinguished mergers and a horizontal agreements (like NSA). In mergers coordination on pricing and any other commercial decision was allowed, but in case of NSA only network investment coordination was assumed. The finding was that NSA has much more limited scope and the aim is to coordinate investment into infrastructure to reduce cost, that may contribute to offer cheaper services to consumers. Secondly, an empirical Fixed Effects Difference in Difference panel model for active sharing in Czech Republic. The finding was that active NSA led to a significant price reduction compared to a control group of other European countries. A structural model of demand and supply for mobile services was used to further decompose the effects and according to the findings, active NSA led to both lower costs and increased network quality. (Maier-Rigaud et al., 2020)

Koutroumpis in cooperation with GSMA Intelligence published also an empirical Fixed Effects Difference in Difference panel model for 20-year long dataset worldwide operators on network sharing and TowerCo carve-out for EBITDA, CAPEX, consumer price and network quality. The finding is that NSA participating MNOs were able to decrease prices and increase network coverage and quality. This was driven by CAPEX reduction and improving return on investment (RoI) in particular visible in 3G sharing. (Koutroumpis et al., 2021)

Summing up, several theoretical and empirical models proved that mobile network sharing, as a horizontal production agreement, is less harmful for social welfare as competition is maintained in retail, compared to full scale merger.

Sector and competition regulation of mobile network sharing

The regulation is balancing to reach cost efficiency, competition and innovation parallel.

The sector regulator NRAs, represented by BEREC Europe-wide followed the OECD guideline on Wireless Market Structures and Network Sharing (OECD, 2014) and its standpoint was published in BEREC Common Position on infrastructure sharing (BEREC, 2018) (BEREC, 2019). The BEREC common position principally assesses the feasibility of infrastructure-based competition and refers to the population density of the areas. In low density rural areas, where infrastructure-based competition is not realistic and feasible, active sharing is allowed, even encouraged. In high density urban areas, where infrastructure-based competition is realistic (in 3-4G and early 5G area), upto partial passive sharing supported, but active sharing not at all. Therefore common position excludes the possibility of active sharing increases consumer welfare compared to independent networks. Instead of assessing possible trade-offs between procompetitive and anticompetitive effects of network sharing, it assumes if the population density increases in a given area, the anticompetitive effects are likely to outweigh the cost reduction effect.

The competition regulator NCAs, represented by DG Competition Europe-wide have the focus to prohibit such cooperation that may prevent, restrict or distort the competition, therefore may decrease social welfare (TFEU, 2011) (TFEU, 2022). However, it handles exemption, where the restriction of competition kept at minimum level and compensated by technical or economic benefits, from which fair share pass through to customers. In other words, cost efficiency benefits considered just on those cases, where it outweighs potential competition drawbacks.

Summing up, the regulatory approach prefers competition an innovation over cost efficiency.

European market landscape for mobile network sharing

Despite from economies of scale point of view, the widespread of countrywide MOCN active sharing agreements would have been rational, only in very few countries applied this solution, like in Denmark, Sweden, Finland, Poland, partial Hungary as well. The vast majority of active sharing agreements are MORAN and very often capital and other few high density urban areas excluded from the cooperation. Bourreau and Pápai provides a comprehensive overview on the European market that displays how regulatory preference shaped the market, overwriting financial rational (Bourreau, 2020a) (Pápai, 2020a)

Conclusion for Network Sharing

European regulators approach on infrastructure-based competition in horizontal merger cases drives the assessment of horizontal production agreements, like network sharing, however latter as cooperation, is less harmful for competition and social welfare. BEREC encourages service-based competition, like network sharing only in low density rural areas, but still infrastructure-based competition preferred in high density urban areas. This regulatory approach worked temporary (in 3-4 and early 5G), but might be more doubtful in matured 5G and 6G with macro and micro cells. Overall regulators not allows to resolve challenge of economies scale and related financial problem of the operators, therefore they were seeking alternative solutions, like asset reconfiguration, infrastructure carve-out.

2.3. TowerCo carve-out assessment

The bottleneck in network sharing regulation, in particular in high density urban areas active sharing was a trigger of alternative market development. As network sharing regulation was unable to resolve fully the conflict of economies of scale and financial challenges on high investment, low return, high debt ratio, therefore low valuation, MNOs launched asset reconfiguration.

TowerCo market development

However infrastructure asset companies development started already earlier in the US or Asia, Europe market waited till compelling financial need to change after limiting merger, network sharing opportunities. The Spanish Cellnex, as a real independent neutral host company identified earliest the niche market reaching the acquisition of more than 100 thousand Towers from MNOs.

MNOs followed three basic strategies regarding asset reconfiguration:

- First is do nothing, preserve status quo that strategy was followed mainly by some market leader incumbent operators, like Magyar Telekom in Hungary (subsidiary of Deutsche Telekom).
- Second is to sell to a neutral host Infrastructure company, like Cellnex or American Tower Company (ATC), who also become active in the market. (eg. Telefonica sold its Telxius captive TowerCO to American Tower, or Hutchinson 3K to Cellnex).
- Third is to carve-out to a captive TowerCo and the ownership remains unchanged under the same group (eg: Vantage from Vodafone, Totem from Orange, but earlier movements like CETIN from PPF O2 Group or GD Towers from Deutsche Telekom)

In case TowerCos, as mainly a first milestone in asset reconfiguration we see 2 further subtrends. On one hand the aim of the divestiture was to prepare to sell the captive TowerCo to a real neutral host TowerCO, but on the other hand in major cases the goal was to preserve the control stake in strategic asset companies and get funding involvement for minority stake. The investor involvement varies from go to stock target (IPO) to direct sale to financial investors. There were MNO plan, in particular from Orange side to form a pan-European TowerCO under MNO stakeholders, but finally it not realized and probably will never happen as financial investors were attracted into the market as minority owners.

An important note that, infrastructure carve-out covers in vast major the passive assets, just in a very few cases active assets in case of captive TowerCos (eg. CETIN). There are several potential reasons for only passive asset involvement, like the simplicity or even regulation, where the active asset sharing caused bottleneck. The intention to reach economies of scale is rescoped compared to network sharing. In sharing case mainly cooperation of two operators covering vertically higher scoped elements of RAN (passive, active and even spectrum) are the root of cost efficiency, while in case of TowerCos the higher number of operators joining (higher tenancy ratio) on a lower scope (mainly passive RAN only) is the savings driver.

Assessment of the carve out

The original ultimate goal was to improve *economies of scale, capacity utilisation and cost efficiency*. This goal is fully met only in case of neutral hosts, where there is reality to increase substantially the number of operators using the infrastructure. The tenancy ratio targets exceed 1.5, compared to 1.0 in standalone operation and 2.0 in network sharing (eg.: participating 2 MNOs use 1 shared infrastructure). In case of captive TowerCos there is limited opportunities for marked tenancy ratio improvement, as remained subsidiary of one of the MNOs, having its retail arm, competing on the end-user market. The Vantage Tower case in Germany shows that was unable to meet committed rollout deadlines for its second key customer, the new entrant 4th MNO 1&1 Drillisch on the German market, where Vodafone was also present at the retail end-user market. The captive TowerCos show no marked cost efficiency improvement opportunity also, as principally nothing has changed with the divestiture.

On the other hand captive TowerCo divestiture was a proper mitigation of financial challenges of company valuation and attract capital to reinvest into the network (eg.: 5G rollout). Infrastructure companies with long term contracts with MNOs for capacity utilisation and fixed yields, gained much better valuation on the market, the EV/EBITDA multiplier is in 15-20 times range, compared to MNOs 5-10 times range, therefore the share prices also exceed European Telcos Stoxx600 Telecom index. (Arthur D. Little, 2021). Key-players, like GD Towers (Deutsch Telekom), Vantage Towers (Vodafone) and CETIN (PPF) realized these benefits when sold minority shares to financial or institutional investment funds and the capital is reinvested in mobile 5G and fixed FTTH rollout.

Regulation of TowerCos:

Divestiture belongs to separation economics topic. Cave described the main stages of separation from accounting separation to legal divestiture (Cave, 2006). Different form of separation might be imposed by regulators mainly in access regulation or even merger approvals (eg.: Openreach carve-out from BT in UK). Or even the relevant operators might offer the separation in order to reach a higher level strategic ambition at the regulator (eg: CETIN carve-out from O2 PPF in Czech Republic). However, in recent asset reconfiguration the infrastructure spin-off is fully voluntary, business driven and has no connection with reaching special regulatory strategic goal.

Beyond asset separation, the TowerCo market is less impacted by regulation as the market goal to attract more operators, like Virtual Mobile network operators (MVNOs) and MNOs by favourable wholesale offers that may help the retail end-user downstream market competition. The competition regulatory concern raised mainly in case of market consolidation at wholesale mobile macro and micro cell infrastructure (TowerCo) relevant markets, where the infrastructure-based competition preference leads the approvals (eg.: Cellnex - Hutchison 3K TowerCo merger in Italy and UK).

The network sharing related empirical model of Koutroumpis in cooperation with GSMA intelligence covered TowerCo subcase partially. The TowerCo related dataset was limited, therefore only one consistent and statistically significant result was found, showing that TowerCo agreements reduced ARPU in 3G area. This finding is similar to network sharing in terms of reducing cost, that enables lower prices for consumers and possible improves quality, enhance speed. (Koutroumpis et al., 2021)

2.4. Other actions for financials improvement and literature conclusion

There are two more actions from EU policymakers that have potential financial impact and might be considered as a mitigation of covering investment gap to Digital Decade 2030 target.

The first controversial topic is the *BigTechs/ Hyperscalers* (eg.: Google, Amazon etc..) *contribution* to network rollout investment in Europe, arguing that these BigTechs trigger the majority of data traffic levels and growth by their data-consuming services to end-customers (Földes, 2022b). MNOs' argument based on sender pays principle, however in contrast to EC standpoint, sector regulator BEREC (BEREC, 2022) and many local governments do not see the compelling necessity of imposing such a "fair share contribution". This action definitely could decrease investment burden and may accelerate rollout to catch-up investment gap, however do not bring a structural resolution for economies of scale problem.

The other controversial topic is *the role of Chinese vendors in fixed and mobile network rollout*. In US and in the UK there is already roadmap for cleaning network from Chinese (mainly Huawei and ZTE) equipment and recently this plan is revitalized under in-depth reconsideration in the EU. This potential action has many political, economic and technology aspects, as in EU Chinese vendor presence can be dominant in certain countries (Strand, 2023). A potential introduction in the EU short run would jeopardize to meet EU Digital Decade 2030 targets, but long run very probably accelerate technology shift to virtualized and open Network with assumed favourable economic and competition impacts. This action in short run would not help to improve MNOs financial challenges, but long run might contribute to a more efficient market

structure with improved economies of scale due to the benefits of virtualisation an open networks.

As a *literature conclusion* regulatory conduct also contributed to two economic European trends. Firstly, majority of national mobile network sharing agreements limited to passive infrastructure, the active sharing’s ratio is much less and only a few agreements cover spectrum. Secondly as vertical, active sharing limited, horizontal cost efficiency cooperations widespread by TowerCO spin-offs, mainly focusing on passive elements.

Summing up, the infrastructure carve-out as an alternative of horizontal mergers and horizontal production network sharing agreements just partially addresses the main, economies of scale problem. In case of neutral host it clearly mitigates the efficiency problem, but in case of captive TowerCos its contribution to efficiency improvement is limited, but definitely helps a lot on MNOs financial challenges related to valuation, stock prices and CAPEX resources.

In order to close the investment gap to Digital Decade 2030 further mitigating actions required to improve economies of scale, cost efficiency that ensure acceptable return on investment.

The *technology shift with virtualisation and open RAN*, as technology enablers might have a positive economic impact by improving competition and innovation that could resolve the acceptance problem of active network sharing in high dense urban areas. Open RAN impacts will be introduced in details in the Section 4.

3. Research methodology for open RAN analysis

The research aim of this paper to explore and describe virtual and open RAN related technology trends and economic implications, focusing on expected procompetitive effects. Table 1. covers selected dimensions of competition analysis framework.

Table 1. Overview on open RAN related research dimensions

Dimensions (market / regulatory goals)	Cost & investment efficiency	Competition (differentiation)	Innovation incentive
Vendor Upstream market			
MNO Downstream market			
End-user retail Downstream market			

Source: Author's own summary

The research methodology aims to determine the matrix points as follows. Virtual and open RAN technology trends directly influence vendor upstream market and expected to contribute to cost decrease and competition increase that has a favourable impact to MNO downstream market. Higher upstream market competition may increase competition and differentiation at MNO downstream market, that allows more intensive competition at retail end-user market and contribute to improvement of social welfare.

The study employs qualitative approach based on secondary analysis of surveys, description and data where were available. The research design after exploratory research contains conclusive researches, in both descriptive and causal approaches. Descriptive research focus on virtual and open RAN as a technology enabler for change in economics. Causal research is limited to theoretical analysis of competition related impacts at general theory level. Quantitative data analysis is limited, as virtual and open RAN is in emerging and infancy phase. Technology transformation leading greenfield and brownfield MNOs data will be introduced.

4. Virtual and open RAN technology and economics assessment

Upcoming year trends require investment-intensive deployment of new network technologies, like FTTx, 5G standalone, edge computing, open RAN and increased integration of terrestrial-satellite communications. Telecom companies have to proactively transform towards a “Network-as-a-Service” model, with value-creation shifting from simply selling connectivity to becoming more and more “orchestrators” of highly customised network needs.

On supply side open RAN concept aims to address several different objectives, including contribution to greater competition, resilience, and innovative entry in the supply chain for equipment and software, that allowing lower the costs. The expectation is open RAN’s potential impact on the upstream supplier market will affect downstream mobile operator market, in terms of the degree of cost/ investment incentives, competition (differentiation) and innovation.

On demand side International Telecommunication Union (ITU) defined 3 main categories for 5G relevant use cases, as follows (1) Enhanced Mobile Broadband (eMBB) that refers to a significantly higher peak and average data speeds and capacity than 4G (10-20 Gbps); (2) Ultra-Reliable and Low Latency Communications (uRLLC) that provides high reliability and real-time communication services (latency less than 1 millisecond); (3) Massive Machine-Type Communications (mMTC), that allows connecting a vast amount of communication devices, with high device density, mainly with low bandwidth needs ($>1\text{m device/Km}^2$)

The importance of supply and demand changes that market moves from “one size fits all” services to customised services on both side. With other words more differentiated supply in higher competition can meet tailored customer needs. Therefore, the research question is whether virtualized and open RAN promotes such competition and differentiation that could make acceptable the active sharing in virtualized and open RAN network also for urban areas.

4.1. Virtual and open RAN, as technology enablers

Traditional RAN, the monolithic telecom infrastructure based on proprietary hardware and closed interfaces, which has meant that operators have relied on a small number of large

suppliers to integrate components into the end-to-end systems that MNOs purchased. However, the legacy network failed to provide the flexibility, scalability and degree of automation as required for a cost efficient service, moving from mass market to tailored demand.

We are facing to a real technology shift in parallel with 5G introduction, far more that we got used to in previous network lifecycle swaps to 4G or before to 3G. Technology shift is happening with creative destruction (disruptive technologies) by network disaggregation, virtualization and open RAN, based on elements of Bourreau & Lemstra, 2022, Pápai et al., 2022b and Open RAN, 2021.

Virtualized RAN

Changes such as introduction of *Software Defined Networking (SDN) and Network Function Virtualization (NFV)*, *open Application Programming Interfaces (“APIs”)*, *Artificial Intelligence (“AI”) / Machine Learning and cloud-native architectures* are also part of the transition to 5G and help cost reduction. Virtualisation means that the importance of the future 5G core network with service differentiation capabilities increasing and SDN/NFV allows decouple of hardware and software of the network. The 5G RAN processing needs is much higher with very low latency, therefore it should be located to closer to the end-user, at the edge of the RAN, named *Mobile Edge Computing (MEC)* from formerly centralised core computing and processing functionalities. The processing needs of low latency applications can also be co-located at the MEC, as part of a distributed public cloud, or integrated with the mobile cloud. From techno-economics aspects virtualisation efforts allows differentiation in Quality of Service (“QoS”) and later network slicing to meet the needs of a diverse set of 5G use cases. Network virtualisation and cloudification developed earlier and independently form open RAN environment, however these functionalities become the enabler of open RAN.

Open RAN

Open RAN is potentially revolutionary new network architecture for mobile networks. It has three main parts, as follows:

- (1) is *Radio Unit (RU)*, where the radio frequency signals are transmitted, received, amplified and digitized. The RU is located near, or integrated into, the antenna.
- (2-3) coming from splitting the proprietary integrated Baseband Unit (BBU) into a *Control/Centralized Unit (CU)* and a remote *Distributed Unit (DU)*, with a new open “midhaul” interface between the two. This approach referred as “disaggregated RAN”. The DU and CU are the computation parts of the base station, sending the digitalized radio signal into the network. The DU is physically located at or near the RU whereas the CU can be located nearer the Core.

The key concept of Open RAN is “opening” the protocols and interfaces between these various building blocks (radios, hardware and software) in the RAN. This enables new services to be configured more flexibly and quickly in the RAN without replacing hardware components. Based on Bourreau, in open RAN different suppliers provide components that customers can then mix and match, which has both benefits and risks (Bourreau & Lemstra, 2022).

The key benefit is that operators can select each network component from the most cost-efficient or high-quality supplier, resulting in a lower total cost and/or a more optimised high quality network. Open RAN may stimulate innovation not only in the provision of products and services, but also in the business models employed by the firms to utilise new technologies.

The main potential risk is that independent vendors may imperfectly take into consideration the complementarities from other suppliers in design phase, may resulting an efficiency loss for the complete system. Further risk can be that only large MNOs have the scale to integrate components themselves, but cloudification and other 5G features may help smaller operators also.

Full differentiating capability of 5G network via network slicing will be available after *5G Standalone (SA) RAN and 5G SA Core network rollout*, that has an extra investment demand over ongoing 5G NSA (Non-Standalone) network, but opens-up full-scale monetisation opportunities for the 5G.

Summing up, related to the technology enablers toward virtualized and open RAN 5G it can be stated that is it a shift to more modular, flexible, software controllable network, supporting extended and dynamic customization capabilities at granular end-user customer level.

4.2. Economics and competition analysis of open RAN

Virtualisation and open RAN are technology enablers for telco-economics transformation. The technology shift from closed proprietary network to open disaggregated networks revolutionize economic opportunities in terms of cost and investments, as well as competition and differentiation, finally in field of incentives for innovation. These competition policy impacts will be assessed in relevant vendor, MNO and end-user retail markets. The discussion will follow the research methodology set in Section 3.

In this section the starting point will be the relevant management theories to set the analysis framework, then the research methodology matrix table will be followed to collect the relevant characteristics of virtual and open RAN.

4.2.1. Applied management theories for open RAN

Four most relevant management theories will be displayed from principal one to the more concrete one direction that provides the best analysis framework to understand economic relevant revolutionary characteristics of virtual and open RAN.

Creative destruction

Creative destruction is most often used to describe disruptive technologies such as open RAN with virtualization, disaggregation and cloudification with edge-computing that in-depth change the telecommunication landscape. Schumpeter in 1942 in *Capitalism, Socialism, and Democracy* book characterized creative destruction as innovation in the manufacturing process that increases productivity. “The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns”- illustrate the same process of industrial mutation – „that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of creative destruction is the essential fact about capitalism.” (Schumpeter, 1942).

Closed and open market organisations

Closed and open market organisation terminology from Farrell in 1998 provides the most relevant description of open RAN impact in vendor upstream market. Open RAN technology brings a change into market structure in the upstream vendor market, from traditional integrated equipment vendors (eg.: Ericsson, Nokia, or Huawei) that sell complete, end-to-end systems to MNOs, to a situation in which vendors sell specific components and MNOs can mix and match components from different open RAN vendors. In the vendor upstream market, the first case can be called as *closed market organisation or system competition* and the second one as *open market organisation or component competition*. (Farrell, 1998)

System and complementary component competition

There is deeper explanation of the previous theory from Matutes & Regibeau. The literature considers at general level markets, where end-users buy systems composed of complementary components. In a closed market organisation, corporates sell complete systems to customers, but not individual components. In an open market organisation, corporates sell only individual components, and users can mix and match the components from different corporates to make their system. (Matutes & Regibeau, 1988).

Competition and Innovation

Aghion found that there is an inverted U-shaped relationship between the degree of competition and innovation. Starting from lower competition, increasing competition stimulates innovation, however, when competition is already intense, further strengthening it may reducing incentives for innovation. (Aghion et al., 2005)

Summing-up, open RAN may open-up the vendor upstream market resulting more intense competition that may will have a competition intensifying spillover effect to MNO downstream market, who are more intensively competing to sell retail mobile communications services to end-users. The closed-open and system-component theories will be applied further, focusing on open market organisation, component competition characteristics to display open RAN.

4.2.2. Open market organisations – cost and investment impact

Cost and investment improvement effect

Open RAN can stimulate the entry of new “specialists” to vendor upstream market, allowing mobile operators at MNO downstream market to mix and match equipment from different vendors, putting downward pressure on equipment costs. When vendors reduce equipment prices for mobile operators, it may contribute to volume driven MNO investment increase in either coverage or capacity (quality) scopes. Bourreau also added, in open markets MNOs have more possibilities of differentiation, therefore higher proportion if investment can related to specific needs of market segments, compared to closed market, primary focusing on standard demand of mass market coverage type solutions.

In practice the 2 types of disaggregation incentives new specialist vendor entry and competition in each disaggregated subsegments, like Hardware - Software or Centralized Unit (CU) – Distributed Unit (DU). Each of these elements can originate from different vendors.

On the other hand, Bourreau lists potential inefficiencies to be mitigated that may risk cost savings. Closed system approach may be more efficient when all components are designed jointly by a single firm, perfectly internalising these complementarities, like specific hardware optimized software. There is an economies of scale in integration (orchestration of complementary components), so integration costs might be higher in open area than is closed one. Large MNOs may have the scale and skills to integrate components in-house, but small MNOs probably need to jointly perform or outsource it. There could be double marginalisation due to more participants of supply chain. (Bourreau & Lemstra, 2022)

Cost commonality

Pápai list an anticompetitive concern also in relation to network sharing in matured (virtualized and open RAN area) regarding the increased commonality of costs may enable tacit collusion on the market. Despite in network sharing wider proportion of total network costs which become common, the level of cost commonality should be evaluated by comparing the common costs to the total cost of services (including retail and general & administration function costs. (Pápai et al., 2020b)

Summing-up virtualized and open RAN expected to provide a net cost saving to MNOs, from that a fair share might be passed through to the end-user, resulting price decrease. Network Sharing acceptance can be improved also by open RAN due to disaggregation originating components from the most cost efficient vendors that could decrease also cost commonality.

4.2.3. Open market organisations –competition, differentiation and pricing impact

Market structure

Open RAN is likely to impact competition, the market structure and the competitive conduct of market players. At vendor upstream market “specialists” (may be active in more component market) develop individual components that are combined ex-post in the market by MNOs. Therefore MNOs can mix and match components from different vendors thanks to open and standardised (interoperable) interfaces between the different components. At traditional closed RAN vendors were “generalists”, all components were developed and integrated in-house and competing on the market selling complete systems.

Market entry

In open RAN area barriers to entry are lower for a vendor providing only a single component, as easier to successfully develop an individual component rather than a complete system. As entry costs are lower, more entry can be expected. Entry with a single component may be first milestone that later can be expanded for further components. In closed markets the value chain is closed to outsiders, as entry into this type of market is only possible via complete system development, creating high entry barriers. Incumbent vendors may have the ability and incentive to restrict or delay the entry of new competitors. The number of available systems may be larger with an open vendor upstream market, allowing MNOs to choose systems that fit.

Differentiation

In open RAN a wider variety of systems will be available to MNOs, as they can mix and match components. This enhances the possibilities of differentiation for MNOs at end-user downstream market also. Service differentiation is beneficial to MNOs as it enlarges their choice sets and allows them to find services that better fit to the need of their end-user preferences in terms of quality and related costs. However, Bourreau says, that differentiation might be in trade-off with prices, as differentiation between competing firms may soften price competition. This means end-users might get a tailored product fitting better their preferences, but the prices may be higher. (Bourreau & Lemstra, 2022)

Pápai from techno-economic side underline also that the differentiating 5G core network domain role will increase, contributing to smaller overall similarity in terms of differentiation in case of matured 5G sharing (Pápa et al., 2020b). The increase in the number of dimensions in which parties can decide to share or not to share will contribute to more differentiated retail offers.

MNO open RAN business models

MNOs might choose between 2 market strategies based on Bourreau. One hand can follow the “*pipeline*” *business model*, in which MNO adopts Open RAN to offer more customized solutions to end-users, but also continue acting traditionally as integrated sellers of communications services at retail mass market. On the other hand, Open RAN represents a *technology platform*, possibly orchestrated by MNOs and offer as a service to other MNOs. It may attract vendor specialists of innovative hardware and software components also and might allow independent service providers to rely on the platform to offer tailored services to specific end-users and create their networks (network as a cloud service). Example for the pipeline case is any traditional MNO, and an example of the platform case is the Rakuten Symphony. In the middle of these solutions there are wide range access service opportunities to MVNOs in case of network sharing.

Price impact

Price impact at retail end-user downstream market depends on production costs and the intensity of competition between market players. Open RAN driving 2 ways the retail end-user prices. On one hand it offers mix & match opportunities to MNOs to select from enlarged vendor base the most cost efficient components, and then fair share of cost savings pass through to customers. On the other hand, open RAN may bring change in the competitive behaviour of market players both on vendor upstream market and MNO downstream market.

However Matutes found that on open market, where users can mix and match components from different vendors may weaken price competition compared to a closed market. The reason is higher elasticity in demand in close market. (Matutes & Regibeau, 1988). Here is the other side of the trade-off between potentially lower prices that a closed market organisation may entail and the wider variety of systems available under open market organisation. For relevant MNOs, the possibility to mix and match components from different vendors suppliers allows them to build a system that fits better with their preferences, which can more than compensate for the higher prices. A closed market potential disadvantage is that, although users can benefit from low prices when joining the system, they may be locked-in ex-post. Open RAN may help to avoid higher ex-post prices.

Summing-up open RAN, as an open market solution improves the market structure via lower entry barriers. Decreasing production cost rooting in mix and match approach and change in competition behaviour that helps benefits originated from vendor upstream market to pass through via MNO downstream market to retail end-user downstream market.

4.2.4. Open market organisations – innovation impact

Incentives for innovation is also a fundamental pillar of competition assessment. Open markets may intensify competition in the upstream vendor market, if the entry of new specialists starts, that brings the innovation to a certain extent. Aghion found an inverted U-shaped relationship between competition and innovation (Aghion, 2005). Based on this theory, the UK sector regulator, Ofcom performed an analysis on competition-innovation relationship related to open RAN. The finding was the current market situation is similar to the starting case, when there is a low degrees of competition, and increasing competition still stimulates innovation, as currently to big generalist vendors (eg.: Ericsson and Nokia) major the European market, so enhanced competition may encourage innovation (Ofcom, 2022).

In an open RAN market MNOs can mix and match components from different vendors at the upstream market. MNOs choose each component from the highest quality provider, resulting overall higher quality, so upstream vendors are incentivised for innovation. The higher quality from a specialist awarded by market entry opportunity and later market share gain spur innovations. As described earlier barriers are low, each hardware, software vendors can compete and innovate based on their comparative advantage skill sets, that allows faster and more independent innovations. Increasing demand expected for tailored digital services as demand is becoming more heterogeneous and differentiated that MNOs have to follow, for which open RAN is an optimal technology. In a closed market MNOs may receive rather general purpose services from vendors, therefore they could offer to end-users less tailored services.

Pápai identified based on EC DG Competition practice in merger control innovation analysis steps that also relevant to describe innovation conducts in open RAN. It contains that (1) innovation must be an essential part of the industry competition, (2) participants must be important innovators, (3) they must be close competitors in innovation also. (Pápai, 2020b)

Summing-up, open RAN incentivise innovation already at vendor upstream market that has a positive spill-over effect to MNO downstream and retail end-user markets.

4.3. Cost efficiency effect of open RAN

Cost saving assumption is the financial driver of MNO's increased interest for open RAN. Based-on latest Analysys Mason survey, conducted in Q2 2022, on 75 mobile and converged operators worldwide that are considering or planning vRAN or Open RAN, including Tier 1 and 2 and challenger operators the TCO reduction is fourth most important commercial objective for open RAN Macro deployment. Network Operators selected even more important the accelerated innovation, supply chain diversity and service agility. (Analysys Mason, 2023b) It is interesting that one year earlier Analysys Mason published a previous survey in which the

TCO reduction was the TOP goal (Analysys Mason, 2022) that show MNOs identify several uncertainties on the size, or even the savings potential of open RAN.

Academic researches also published on open RAN related savings potential. Bouras published an experimental result on deployment of virtualized small cell base stations and the network softwerisation can help MNOs to realize 63% OPEX reduction and a 68% CAPEX reduction compared to traditional rollout. (Bouras et al., 2016). Lehr expects cost savings from Network Function Virtualisation, as NFV allows avoiding the unit costs of supporting functions per locations, and supports scalable capacity expansion to meet easily to aggregate demand (Lehr & Stocker, 2023). Virtualized network aims to put the functionality (NFV) of customized equipment into software programs that run on commercial off-the-shelf (COTS) hardware or in the cloud. Both mass market standard hardware and the cloud be more cost efficient as the vendor lock-in proprietary hardware.

The Japanese operator, Rakuten, who has chosen the technology platform provider business model, disclosed already cost savings ambitions and results when introduced its Rakuten Symphony platform. According to the report in 5G deployment with Rakuten Communication Platform (RCP) 40% CAPEX and 30% OPEX reduction is achievable. It also lists that in CAPEX 60% Hardware and 50% deployment cost savings expected driven by fewer equipment and capacity pooling. In OPEX the largest savings potentials are in field maintenance (-70%, due to fewer site and automation), Operation centres (-50%, due to automation, scale, centralisation) as well as rental and electricity (-30%, fewer site, optimized footprint and power consumption). (Rakuten, 2020)

Consultancy firms also published savings potential related to open RAN, Arthur D. little introduced 37-44% TCO savings range, in which in OPEX might have a slightly higher efficiency room (Arthur D. Little, 2020). Analysys Mason put publicly available a study on how MNOs can leverage on 30% TCO savings potential with complete Business Case scenarios, assumptions, technology specifications. This report also called the attention which are the key-lever of savings from technology deployment aspects. (Analysys Mason, 2022)

Summing-up virtual and open RAN expected to provide a substantial savings, but concrete configuration can may cause higher deviations.

4.4. Market and regulatory development related to open RAN

Technology products lifecycle and the adoption of new technologies is not only a technology function sub-question, but a complete corporate strategy decision for the MNOs. Rival, newcomer, greenfield operators' strategy might deviate from incumbent brownfield operators. Due to the fact that virtual and open RAN technology shift development has arrived rather in the middle of lifecycle in between 5G and 6G rollout the, first mover strategy benefits have not been clearly visible.

Actual market development

Challenger communication service providers (MNOs), mainly new entrant greenfield operators into the matured market would like present a dynamic growth story. Although these MNOs might have an advantage not to build out 2-3-4G, just focus on 5G or later technologies, they

suffer from front investment burden and lack of scale in short and mid-run operation. Therefore new greenfield operators the first candidate to adopt new, even disruptive technologies that may result a cost advantage at unit level, compared to incumbent brownfield operators with stable customer base. New operators unlikely to perform better than incumbent operators, if just adopting market leader's strategy, so "creative destruction" needed to catch-up incumbents.

In field of virtual and open RAN the market development of three key *greenfield MNOs* are analysed, as the Japanese Rakuten, the German 1&1 Drillisch and the US Dish. All of them chose the virtual open RAN solutions with private or public cloud in cooperation with BigTech/hyperscalers. The of Rakuten is the most significant market player not just because of worldwide first open RAN innovator, but also a technology platform provider. Unfortunately, Rakuten's market development is very limited around 2% market share, after 3-year operation, due to rather external Spectrum resource and marketing strategy difficulties, than the failure of open RAN concept. The 4th German MNO, 1&1 was the first adopter of Rakuten's technology platform, but it bis market development is in delay due to Vantage Towers infrastructure asset partner delayed the site deployment. The 4th US MNO, Dish with a public cloud-based network also faced to challenges due to size of the country to be covered on competitors level user/site ratio. Summarizing current status of rival MNOs, the market underperformance is related to rather challenger position than disadvantages of selected new open RAN technology.

Incumbent brownfield operators with legacy network operations still wait and try to shape open RAN development also joining for O-RAN Alliance and joint development in frame of common Memorandum of Understanding (MoU) preparation by Deutsche Telekom, Orange Telefonica, Vodafone, and Telecom Italia. Almost all operators disclosed rollout plan on pilot open RAN sites and smaller areas. Among the MoU sign-off members Vodafone made the published the most advanced pilot results and mass-market commercial rollout plans. Vodafone's first open RAN polit and commercial launch were in Irish rural areas in 2020 and in 2023 UK urban commercial open RAN operation is announced already (Vodafone, 2023b). Vodafone in 2022 set a public target to reach 30% open RAN share among operating masts for 2030 (Vodafone, 2022). From this paper aspect the most significant information is that, Vodafone and Orange announced in 2023 that in European countries with dual presence at rural areas shared open RAN 5G rollout will be launched and the polit site will be in Romania. (Vodafone, 2023a)

Forecasted market development

Analysys Mason consultancy estimates as a mid-case (middle income countries, moderate take-up) for open RAN adoption of the market, that 54% of subscribers will be served by open RAN networks at the end of 2030. In case of slow take-up scenario 26%, in case of fast take-up scenario 86% is the relevant subscriber rate. In low income countries the growth can be a little been even higher due to higher open-ness for cost efficient solutions. (Analysys Mason, 2021). In 2023 Analysys Mason forecast that virtual and open RAN revenue share out of total RAN at vendor upstream market revenues, could go up form below 10% in 2022 to over 70% in 2028. This would mean complete change between open RAN versus Traditional RAN in 2022 – 2028 time range (Analysys Mason, 2023a).

Regulatory Standpoint

European sector regulator BEREC started the investigation of open RAN topic in wireless network evolution workgroup. The first published material drew 4 scenarios for most realistic developments of the 5G equipment and services supply market till 2030 (BEREC, 2021). The

study analysed economic, technological, environmental, and social impacts for each scenario, covering key European Commission and stakeholder concerns, including market competition, costs (OPEX & CAPEX) requirements. The identified scenarios are (1) incumbent players driving 5G, (2) slow pace of 5G rollout, (3) open RAN as a game changer, (4) 5G for Big Techs. The open RAN, as game changer scenario is the most relevant for this paper. BEREC assumes in this scenario that Open RAN is a deep game-changer in the 5G supply chain with new players (mainly non-European) entering into the European RAN market. Decentralized, disaggregated and fully virtualized Open RAN networks may serve Europe and this potentially stimulated in mainly due to increased market competition and new suppliers in the RAN domain.

Summing-up open RAN market developments has started. Rival MNOs are in rollout phase however still challenging the go to market strategy. Incumbent MNOs started pilots, later commercial usage also from rural to urban areas and open RAN rollout targets even shared open RAN deployments are announced already. Till 2030 dominant role of open RAN predicted and regulator also identified as a potential scenario, but at this stage no intervention needed.

4.5. Conclusion of open RAN competition assessment

Virtual and open RAN revolutionize technology enablers to transform telecommunication industry from closed market organisation structure to open market organisation structure in the vendor upstream market. Conclusion of this section that this technology shift intensifies upstream market competition by lowered market entry barriers and the diversity of new specialist vendors that allows MNOs to provide more cost efficient, differentiated and innovative offers to meet tailored end-user need. Telecom network component’s upstream market transformation has favourable spillover effect to telecom network operator MNOs downstream market, as more differentiated and innovative network component inputs enable them to provide more differentiated, customized services to tailored end-user customer demand.

In Table 2. key-characteristics of the markets and competition assessment points are summarized for open market organisations.

Table 2. Overview on open RAN related research findings on open market

Dimensions (market / regulatory goals)	Cost & investment efficiency	Competition (differentiation)	Innovation incentive
Vendor Upstream market	low entry barrier for cost efficient lean specialist vendors	disaggregated component specialist	innovative components offer to market entry & gain market share
MNO Downstream market	mix & match, based on lower cost, highest quality	differentiated components allow customized offers	innovative components provide comparative advantage

Dimensions (market / regulatory goals)	Cost & investment efficiency	Competition (differentiation)	Innovation incentive
End-user retail Downstream market	affordable prices	tailored, higher quality offers top-on improved mass market services	innovative services for latent customer demand

Source: Author's own summary

Virtual and open RAN brings the point when network capabilities on supply side at upstream market can meet customer demand side at end-user downstream market. Virtual open RAN with network slicing allows MNOs to provide on-user-demand logical separated network partitioning, software-defined on-top of our common physical network infrastructure. User demand can vary in terms of network parameters, like throughput, latency, scale, Quality of Service, availability, redundancy, security, etc. These demands typically evoked at Business to Business (B2B) business customer segment, there is not really a reason why Business to Customer (B2C) consumer segment could not benefit from that slicing as well, like demands on gaming/VR/AR, consumer smart homes, consumer vehicular applications, etc.

Summing-up virtual and open RAN economic impacts, via vendor upstream market intensified competition and innovation the MNO downstream competition, differentiation and innovation is increased. The real question of this paper, whether these MNO downstream market competition benefits in combination with network sharing can provide the lacking element for regulators to approve higher scope active network sharing.

5. Open RAN economic impact assessment for Network sharing

Mobile network sharing as a horizontal production agreement is a more favourable alternative of horizontal mergers. MNOs can realize the major part of the merger savings, however only the RAN technology network production function of competitors consolidated, while competition retained in core network function and all other business (eg.: sales marketing, customer care) and overhead (eg: strategy, communication) functions.

Despite these acknowledged economic statements, regulators apply similar approach to assess network sharing, like in case of full-scale merger. European regulatory preference is on infrastructure-based competition between parallel infrastructures compared to service-based competition on same common infrastructure by MNO-MVNO or MNO-MNO in case of network sharing. The higher scoped active network sharing with higher cost savings potential, so the better economic of scale is also acknowledged by BEREC. However only in rural network sharing allowing and even encouraging active sharing, while in high density urban areas BEREC assesses that network sharing procompetitive benefits are overcompensated by anticompetitive ones and lack of infrastructure-based competition.

Virtual and open RAN brings at that point extra benefits to support country wide network sharing acceptance, including active sharing with higher economies of scale at high density urban areas also when macro and later micro cells will require further investments.

Notwithstanding even clearer open RAN concept, the feasibility just in infancy phase from pilots to commercial rollouts form rural areas to high density urban areas.

Table 3. describes the main current cases of network sharing, open RAN and density dimensions in the EU

Table 3. Overview on network sharing and open RAN combinations in EU

Dimensions (sharing/open RAN)	open RAN rural	open RAN urban
active RAN sharing rural	active sharing: encouraged; open RAN: piloted even commercial usage shared open RAN rollout: announced (Vodafone-Orange)	N/A (suburban like mixture) network sharing: case by case decided open RAN: more pilot cases
active RAN sharing urban	N/A (suburban like mixture) network sharing: case by case decided open RAN: more pilot cases	active sharing: discouraged open RAN: very few pilot, one commercial announcement

Source: Author’s own summary

The table shows that in low density rural areas network sharing and open Ran can create feasible and regulatory acceptable solution to mitigate economies of scale, cost efficiency and asset utilisation concerns. In case of high-density urban areas active sharing not supported, but virtual and open RAN may provide such additional features that require a reevaluation of regulatory standpoint.

European regulators insist on infrastructure-based competition, what in traditional RAN period meant at least two parallel proprietary physical infrastructure. However, in the new virtual and open RAN with network slicing options allows MNOs to operate multiple virtual networks over a single shared physical network. Software that operates network, becomes more important for determining the network quality, competition, and differentiation, than the underlying hardware. This is also valid if the physical infrastructure is shared not only for passive, but also for active network elements.

The consequence is that, both the definition of infrastructure and the regulatory objective should be reassessed in case of network sharing assessment. If the regulatory aim is to stimulate competition, differentiation and innovation, that open RAN can bring, as moves these capabilities of RAN segment to software side on the infrastructure, besides core networks differentiating capabilities unattached. The hardware part of infrastructure will lose significance in competition, but will gain more importance in cost efficiency through COTS standard servers. The regulatory consequence is that, there is no real reason to insist on parallel physical infrastructures even in urban areas as competition can be preserved even simulated on software based. Therefore the active sharing extension to at least hardware segment side would not harm competition and innovation, but could contribute to cost efficiency, resulting overall not worsening, indeed improving social welfare.

EC DG Competition already acknowledged in Czech active network sharing investigation that the case scope is 4G, as 5G might have different characteristics (European Commission, 2019) to be assessed that is good sign that policymakers are also getting familiar with these trends. Vodafone and Orange announced shared open RAN Europe-wide plan shows that MNOs would like to move into this rational direction, however as far as technology developments will allow these initiatives should be allowed to extend for high density urban macro and micro cells. In the high-end segment, represented by urban micro-cells the asset utilisation is equal importance concern, like in low-end rural segment as the investment value/user could be same size.

6. Conclusion and future outlook

The reach of EU Digital Decade 2030 targets for full fixed and mobile coverage might be in risk, as due to lack of economies of scale, return on investment often lag behind cost of capital, therefore the whole European telecommunication sector undervalued. On European fragmented telecommunication market operators call for market consolidation at least market cooperation to improve economies of scale, cost efficiency via better asset utilisation. Horizontal merger opportunities are limited due to European regulators preference on infrastructure-based competition over service-based competition that in practice meant to keep 4-player market as long as possible.

Although the alternative horizontal production agreement mobile network sharing's procompetitive advantages are acknowledged compared to full scale horizontal mergers, similar competition assessment applied. Active mobile network sharing with higher economies of scale potential in high density urban areas are discouraged by the regulators as it constrains infrastructure-based competition.

Virtual and open RAN with software defined network and network function virtualisation allows the competition to move to the software that runs over the hardware and to the delivered services. This revolutionary technology shift implies a high degree of decisional autonomy on the network sharing participants, and may allow active network sharing that were assessed problematic under competition law. Virtual and open RAN permit operators to independently control network capacity and quality parameters even when in active sharing. Therefore active RAN sharing may no longer pose the same threat for an operator's independence and differentiation that may require a change in paradigm for network sharing under competition law. This valid not only for high density urban macro cells, but in particular for small cells with optic backhaul. In order to lift legal uncertainty, the European Commission may update the TFEU guideline or even issue separate one, to examine how virtual and open RAN may affect

the analysis and in particular the traditional “infrastructure” or “active-passive” network sharing paradigm which drives many competition law decisions. Policymakers may acknowledge that there will be a different range of competition/innovation trade-off that will emerge in a future 5G environment, where virtual open RAN implies a break between services and equipment and as well between network services and network infrastructure.

European Commission indirectly acknowledges the disconnect between financial interests and competition expectations, however ongoing initiatives could just partially mitigate MNOs financial difficulties, but not resolve the lack of economies of scale rooted in market structural problems. Imposing fair share contribution on sender pays or even solidary fund contribution principles might increase MNOs’ investment incentives, but not address perfectly the economies of scale concerns. Revitalizing the clean vendor policy against Chinese vendors short run might cause more financial concerns, but from mid run might be a real push to open RAN transition that might be beneficiary both to MNOs and consumers, improving social welfare.

Future scope

Based on technology shift and enabled economics trends, as network sharing, TowerCo set-up, virtual and open RAN MNOs, strategic business decision making worth to be analysed creating key relevant scenarios for European market. The less conservative scenario contains no or passive network sharing, no or only MNO wing TowerCo carve-out and only proprietary RAN operation with macro cells. The most advanced scenario covers active network sharing, neutral host TowerCos utilisation, virtual and open RAN with macro and micro cells. Purpose of the analysis to demonstrate which scenario could parallel increase corporate value without harming competition and social welfare.

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