White Paper

On

Infrastructure Sharing

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Executive Summary

Overview of this report

The global telecommunication market is transforming towards a digital, sharing and interconnected economy. Mobile network operators provide connectivity and communications service over deployed network infrastructure (whether owned or leased). The roll-out of mobile networks requires high sunk investments and the need to recover these costs. The need for telecommunication networks with higher capacity is becoming a reality all over the world. However, there is a recognized disparity between broadband availability in urban and rural areas. It is costly to build telecommunications networks in rural area. The rapid development of new-generation applications requires upgrading the access infrastructure a necessity for higher throughput requirements and communication demands. These applications include high-definition television (HDTV), peer-to-peer (P2P) applications, video on demand, interactive games, e-learning, and use of multiple personal computers (PCs) at home.

Service and network providers are challenged to provide this higher-capacity access to the end user and offer wider services. Consequently, new Internet infrastructure and technologies that are capable of providing high-speed and high-quality services are needed to accommodate multimedia applications with diverse QoS requirements.

Network sharing ideas and proposals for different approaches started to appear after the UMTS licenses were granted in Europe in the 2000s.

Recent industry trends show higher awareness and readiness towards network sharing, also among incumbent operators. Where emerging/developing market operators are looking at economic option for coverage and capacity growth, operators in mature markets are seeking cost optimization and technology refresh, by a step further by establishing a joint venture currently aiming at optimizing access transmission through sharing leased lines and microwave links.

This paper deals with the different levels of network sharing, benefits and disadvantages of each alternative technology sharing and the various technical and regulatory constraints linked to the deployment and operation of shared networks.

1. Types of Infrastructure Sharing

Mobile infrastructure sharing (both passive and active) describes the process by which operators share infrastructure to deliver a mobile service to end users.

Passive infrastructure sharing is the sharing of the passive elements of network infrastructure such as masts, sites, cabinet, power, and air conditioning. Passive Infrastructure is becoming popular in telecom industry worldwide

Active Infrastructure sharing is sharing electronic infrastructure. This includes: Spectrum, Switches, Antenna, Transceivers, Microwave equipment.

2. Dynamics of Infrastructure sharing

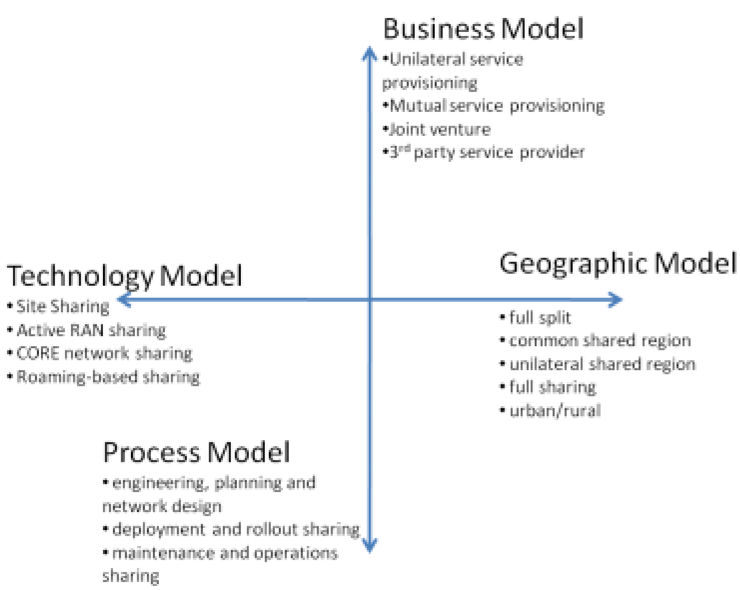
Network sharing can be characterized into four main dimensions:

a. **Business Model** - describes the parties involved and the contractual relationship between the parties.

b. **Geographic Model** -describing each operator's physical footprint.

c. **Process Model** - determining the services to be shared.

d. **Technology Model** - describing the technical approach used for sharing.



3. Why Infrastructure Sharing?[1]

a. Difficulties in acquiring sites for access network

Network densification to address coverage demands in indoor environments has led to increasing difficulties in acquiring sites for radio access network (namely, base stations).

This arises mainly from two factors:

- Firstly, the spaces within buildings are usually confined and reasons of aesthetics/civil works limit the choice even further.
- Secondly, having more than one mobile operators further complicate the problem because the mobile operators will have to compete for a few sites.

In this context, it would be more rational for operators to share in-building infrastructure or at least the transmission lines to share the burden while achieving reasonable coverage.

b. Cost of 5G Deployments to meet throughput demand

5G networks are expected to incur a higher cost of deployment to meet throughput requirement and demand. Radio access networks already comprise the largest portion of the cost in network deployment and operation. To meet mobile broadband demand, 5G is likely to be offered on higher frequency radio spectrum above 6GHz. This means that cell offers smaller radius of coverage and so achieving widespread coverage may be challenging.

c. Enabler to rationalize legacy networks

Infrastructure sharing can be a step to enable rationalization of legacy networks such as 2G or 3G networks. Considering the falling revenues of 2G/3G networks and higher spectral efficiencies of next-generation networks (4G and 5G), many mobile operators are already rationalizing these legacy networks. However, completely closing the legacy networks are very challenging.

d. Technical Enablers for Infrastructure Sharing in the 5G era

Introduction of NFV (Network Function Virtualization) and SDN (Software Defined Networking) in cellular networks could also accelerate mobile network sharing. NFV and SDN enable an operator to use commodity hardware in place of physical equipment and all instances of network entities are virtualized and exist as logical entities (i.e. have various logical instances of a network entity such as S-GW on a single physical node). Furthermore, NFV and SDN enable network slicing, which allows "slicing" of one physical network into a number of virtual networks possessing a different quality of service and topology, allowing operators to deploy virtual networks with a different set of requirements on physical infrastructure.

[1] https://www.gsma.com/futurenetworks/wiki/infrastructure-sharing-an-overview/

e. Diverting investment to other innovation

Infrastructure sharing enables operators to focus on the competition in the service layer regardless of the extent of the sharing. Operators can share whole or strategically unimportant parts of its infrastructure to share infrastructure costs while providing acceptable performance. Furthermore, these savings can facilitate mobile operators' migration to next-generation technologies and provide its customers with the latest technology available.

f. Cost effective means to address capacity demand growth

Mobile operators are also under pressure to extend the capacity of the network due to the significant growth of traffic that is being handled by mobile networks, traffic that is expected to grow even further in the future. This means that the cost to handle traffic will increase and worsen the profitability of operators.

In this context, mobile operators need to employ cost-effective methods such that accommodation of the increased traffic does not require similar magnitude of growth in infrastructure cost. Traditional infrastructure deployment scheme can only bring limited cost reduction even under tight cost reduction pressure, but infrastructure sharing enable significant cost reduction for mobile network infrastructure deployment.

g. Social benefits

Major social benefits come directly from the economic benefit, where mobile operators can direct saved cost to the customer in pricing. In addition, infrastructure sharing can help reduce energy consumption and radio emissions of networks.

4. Types of network sharing

We have classified sharing broadly into five categories:

a. Site sharing

Site sharing, involving co-location of sites, is perhaps the easiest and most commonly implemented form of sharing. Operators share the same physical compound but install separate site masts, antennas, cabinets and backhaul. This form of sharing is often favored in urban and suburban areas where there is a shortage of available sites or complex planning requirements.

b. Mast (tower) sharing

Mast, or tower, sharing is a step up from operators simply co-locating their sites and involves sharing the same mast, antenna frame or rooftop. Each operator will install their own antennas onto a shared physical mast or other structure. The mast may need to be strengthened or made taller to support several sets of antenna. As for site sharing, operators may share support equipment. Operator coverage remains completely separate.

c. RAN sharing

RAN sharing is the most comprehensive form of access network sharing. It involves the sharing of all access network equipment, including the antenna, mast and backhaul equipment. Each of the RAN access networks is incorporated into a single network, which is then split into separate networks at the point of connection to the core. MNOs continue to keep separate logical networks and spectrum and the degree of operational coordination is less than for other types of active sharing.

d. Network roaming

Roaming may also be considered as a form of infrastructure sharing though it does not involve use of common network elements. In the case of roaming, the traffic of one service provider is routed on another service provider's network. The service providers enter into roaming agreements for this purpose.

Roaming can be further divided into the following categories:

- National roaming.
- International roaming.

Roaming produces benefits primarily through delayed or reduced investment in network infrastructure. This is particularly beneficial to new entrants who require time to establish coverage footprints similar to that of incumbents. However, it is generally not seen as a long-term solution for operators as it reduces their own margin potential and agreements typically do not count towards roll-out obligations imposed by regulators within operators' licensing agreements.

e. Core network sharing

At a basic level, the core network consists of:

- Core transmission ring.
- Switching Centre (with the home location register (HLR)).
- Billing platform.
- Value Added Systems (VAS) that represent logical entities and may also form part of the core network.

The core network may be shared at one of two basic levels, namely the:

i. **Transmission ring**

Where an operator has spare capacity on its core ring network, it may be feasible to share this with another operator. The situation may be particularly attractive to new entrants who are lacking in time or resources (or desire) to build their own ring.

They may therefore purchase capacity, often in the form of leased lines, from established operators. Fixed network operators, such as British Telecom and Cable & Wireless, which sell capacity on their network on a wholesale basis often provide operators with an interim mechanism to roll out a network quickly while they make arrangements to implement their own architecture. However, if both companies use the same joint transmission and switching core then their services will become more aligned as they will have the same infrastructure capabilities. Any service, function or process that one operator implements can be replicated by the other as they have the same infrastructure capability.

ii. Core network logical entities.

Core network logical entity sharing represents a much deeper form of sharing infrastructure and refers to permitting a partner operator access to certain or all parts of the core network. This could be implemented to varying levels depending on which platforms operators wish to share. A simple example may be sharing the equipment identity register (EIR) function, which on its own may be expensive but as a pooled resource between operators becomes more attractive.

5. A closer look at active sharing[2]

a. Multi-operator RAN (MORAN)

In the MORAN model, only the RAN elements are shared. Specifically, the base transceiver station (BTS), base station controller (BSC), node B and radio network controller (RNC) are split into multiple virtual radio access networks, each connected to the core network of the respective operator. Operators continue to use their own dedicated frequency bands.

b. Multi-operator core network (MOCN)

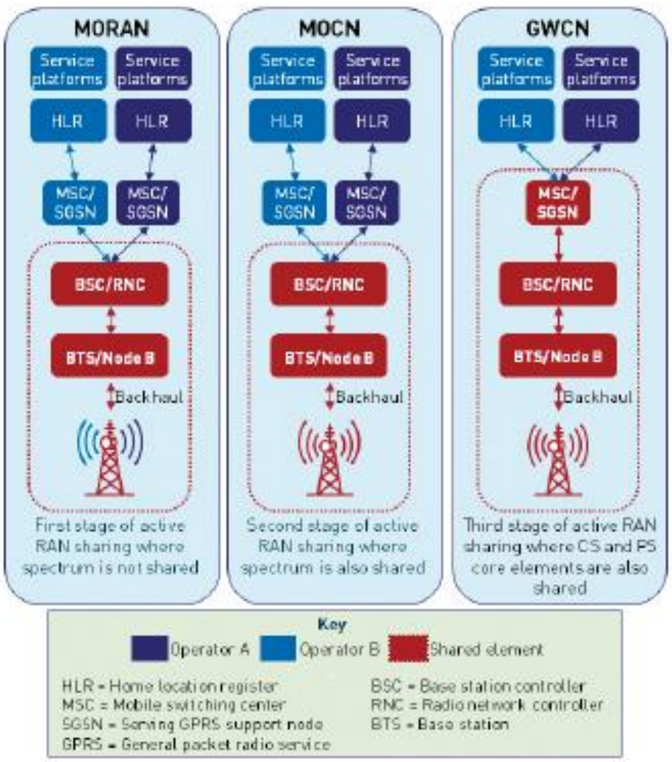
MOCN is similar to the MORAN in that the operators' core networks remain separate while the RAN elements are shared. In addition, MOCN shares the same base station radios and uses spectrum pooling, which increases the number of usable frequency blocks. 3GPP Rel6 TR 23.851 has enabled BTS radio sharing. It allows each cell in the shared RAN to broadcast all sharing operators' identities and other relevant information, including their NMO (network mode of operation) and common T3212 (location update timer). This, of course, requires Rel6 terminals/UEs to fully function.

[2] Commscope white paper on Sharing an antenna doesn't mean giving up control

Participating operators in this arrangement tend to be similar in terms of market presence and spectrum assets in order to create an equitable arrangement.

c. Gateway core network (GWCN)

The GWCN model takes MOCN sharing a step further; not only do the operators share a common RAN, but elements of the core network are also shared. These include the mobile switching center (MSC), serving GPRS support node (SGSN) and—in some cases—the mobility management entity (MME). This configuration enables the operators to realize additional cost savings compared to the MOCN model. However, it is a little less flexible and regulators may be concerned that it reduces the level of differentiation between operators.



6. The unique role of the antenna in a shared network

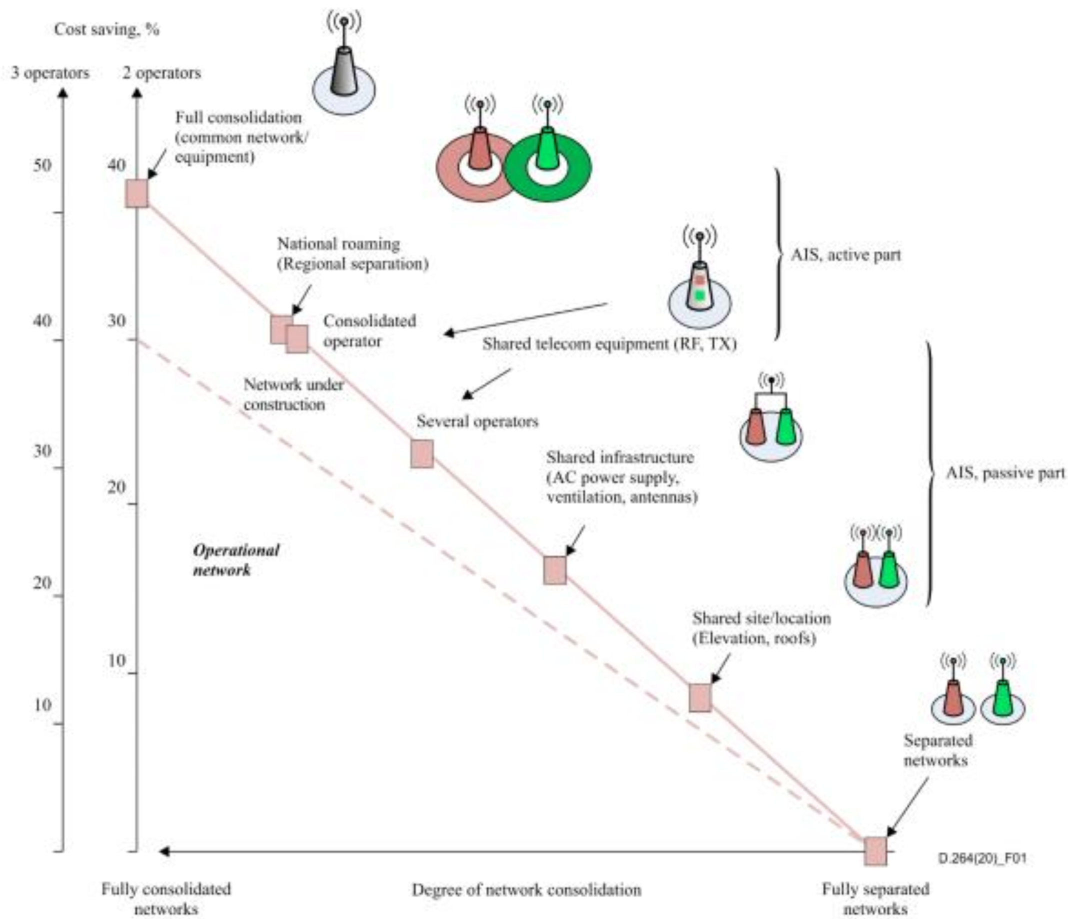
A site's antennas are unique in that they are key considerations in both passive and active network sharing agreements. The variety of network sharing scenarios in which they are used has led to manufacturers engineering a high degree of versatility into the antenna's architecture.

Therefore, base station antennas have evolved to become highly complex—and their proper use in network sharing arrangements can appear enigmatic. Antenna sharing between multiple operators, for example, is often seen as being restrictive in terms of optimization—and costly when compared to adding another regular antenna.

7. Potential challenges

Because it interacts with so many different RF elements—TMAs, SBTs, radios, RRHs, etc.—a shared antenna presents a variety of technical challenges and trade-offs that must be thoughtfully considered

8. Cost savings depending on the selected option of network sharing[3]



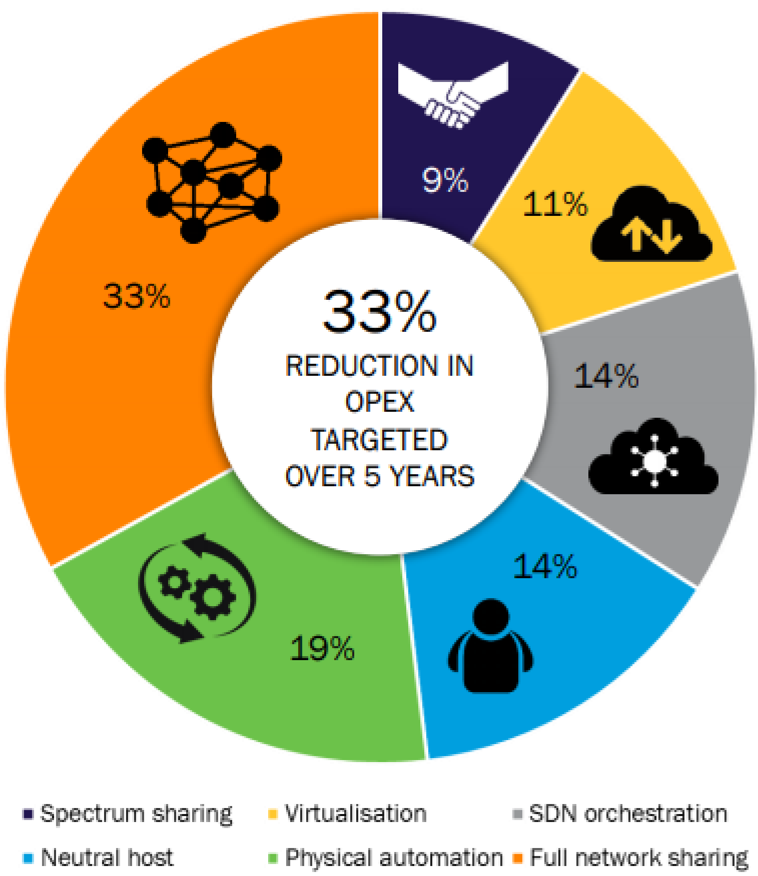
9. The impact of 5G and next generation networks on mobile opex spending[4]

For many operators, one of the key promises of 5G was to reduce opex significantly, by introducing higher levels of virtualization, automation and software-defined networking (SDN). However, even before 5G is commercially deployed, it has become clear that these approaches will not quickly deliver savings of the magnitude targeted by MNOs. Operators will need to adopt other tactics.

[3] https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-D.264-202004-I!!PDF-E&type=items
[4] https://www.analysysmason.com/globalassets/x_migrated-media/media/analysys_mason_5g_opex_strategy_sample_oct2018_rma163.pdf

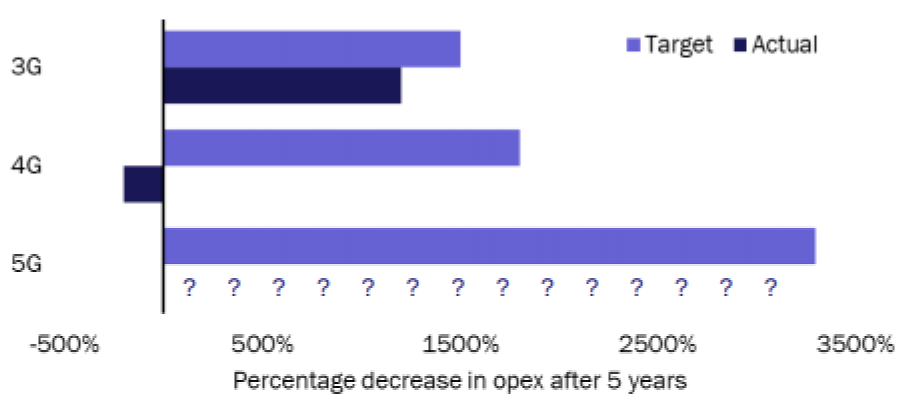
Some of these, such as increased sharing of networks and spectrum, are already being demonstrated by a new breed of disruptive, opex-light operators.

a. Breakdown of targeted 5G opex savings:

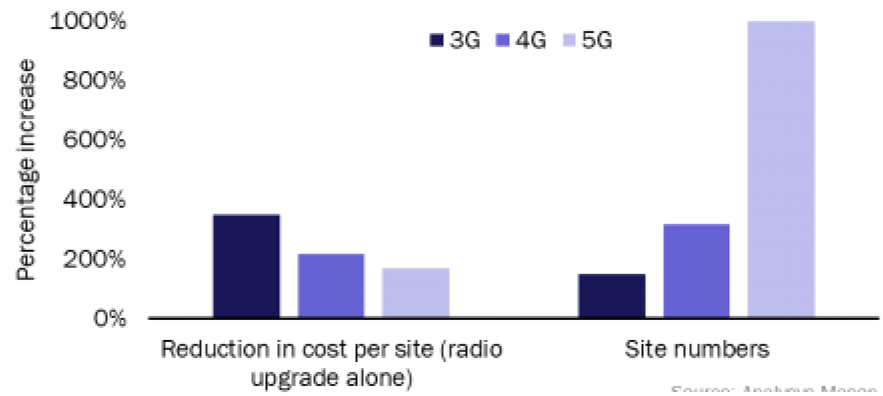


Mobile operators' opex has been growing more quickly than their revenue since 2008 and they have consistently missed targets to reduce it.

b. The gap between opex targets and reality:



They have reduced the cost per site, but the number of sites has increased significantly with each mobile generation.



It is therefore essential to adopt a radically different approach to planning and running the new next generation networks, in order to slash not just the cost per site, subscriber or kilometre, but the absolute opex levels.

Several characteristics of next-generation platforms support radical opex reduction, but only if harnessed in parallel and with a coordinated plan on how to transform the cost model.

c. There are three approaches to opex reduction for MNOs:

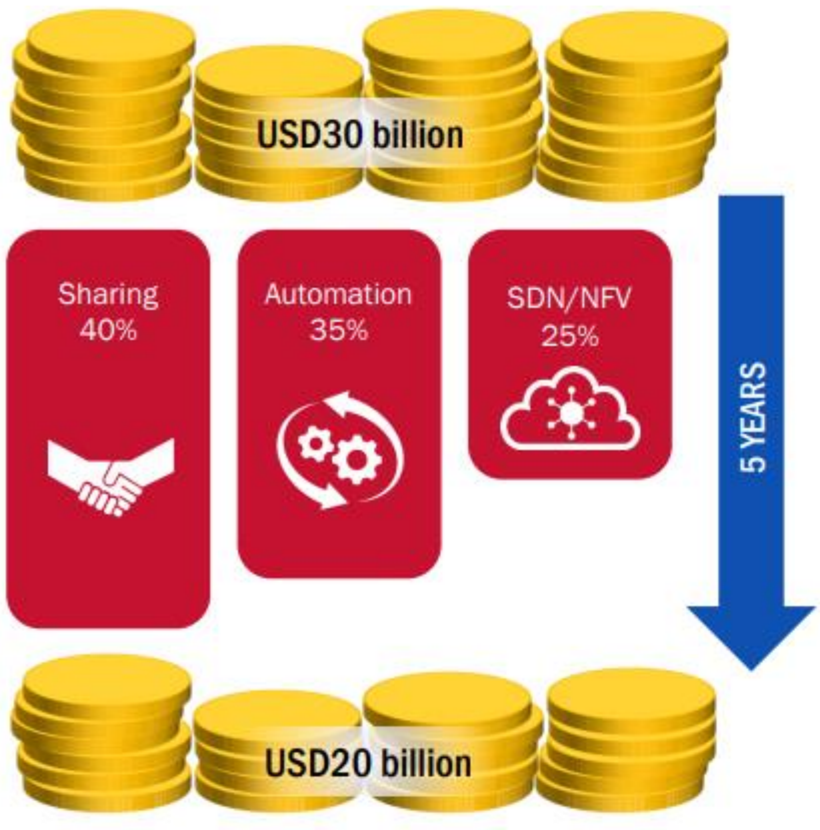
i. Make an early start with the implementation of the virtualization and software-defined networking (SDN) strategy. The opex savings will not be immediate and they will often be forward-looking; only if approaches such as slicing are successful at generating new customers or services will the overall cost per customer come down.

ii. Apply automation to every process, not just those affected by SDN. Activities such as site maintenance, spectrum utilization, network optimization and customer service can all be heavily automated, and eventually, some can be AI-enabled. This can affect 35% of a typical opex budget.

iii. Be open to much more equipment, spectrum and asset sharing. Partners may be other MNOs or new stakeholders such as industrial or web-scale companies. This will shift the capex/opex ratio towards the latter, but can also reduce the absolute opex if the overall total cost of ownership (TCO) is reduced enough.

Together, these approaches can deliver a reduction in absolute opex of at least one third over a 5-year period.

d. The contribution of different factors to a 33% reduction in opex:



10. Telecom Revenue and OPEX Worldwide

Total opex worldwide will remain high until at least 2025, but it will grow more slowly than revenue, and will increasingly support new revenue growth enablers[5]

Operators have set ambitious cost reduction targets in recent years, and some, such as AT&T, Deutsche Telekom and Telenor, have made significant progress in increasing their opex efficiency.

5 https://www.analysysmason.com/contentassets/b3f5e39d0bce472995caa931d32f15ba/analysys_mason_telecoms_opex_forecast_sample_aug2020_rdns0.pdf

However, worldwide forecast shows that telecoms opex will fall at a **CAGR of just 0.21% between 2019 and 2026**.

Telecoms revenue has grown gradually, but fairly consistently, since the global financial crash of 2008–2009. This growth is becoming harder to sustain, especially in competitive markets, and is expected to slow in the 2020s, from a CAGR of over 2% in 2009–2019 to 0.33% in the period to 2026. However, operators continue to protect revenue growth, even at the expense of margins, hence why some areas of increased opex relate to strategies to drive new revenue. Opex savings achieved in one area, such as the network itself, are often re-invested in growth enablers rather than supporting higher EBIT margins. This is not to dismiss the goal of opex efficiency; opex will grow more slowly than revenue until 2022, and will then fall.

Figure 1: Telecoms revenue and opex, worldwide, 2009–2019

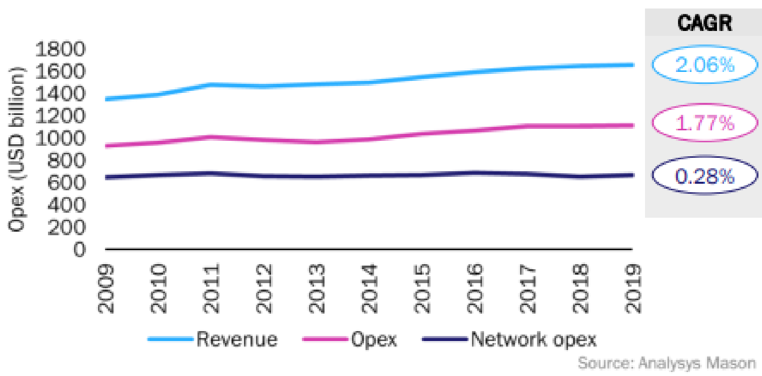
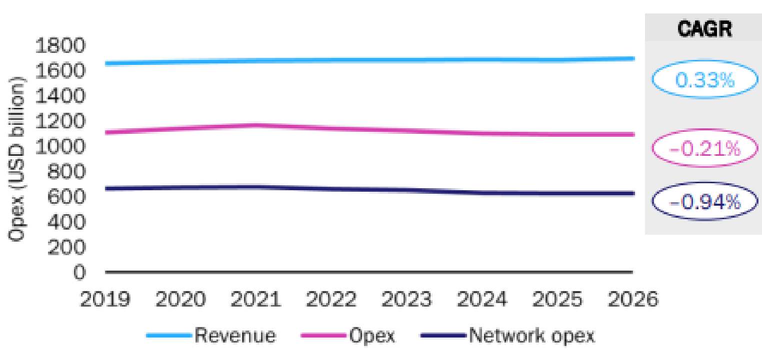


Figure 2: Telecoms revenue and opex, worldwide, 2019–2026



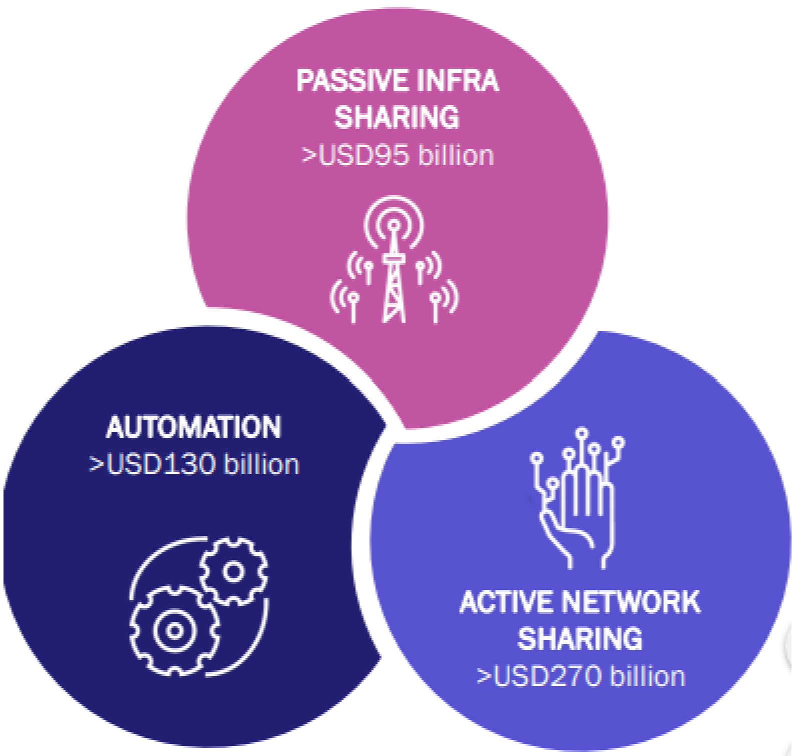
Automation and asset sharing will play a big role in limiting opex growth, and eventually in reducing absolute opex and unlocking value and new investment .

Greater automation of networks, IT, customer and general processes and increased sharing of active networks and passive infrastructure (especially for wireless) are the most important operational changes for operators to reverse opex growth and start to drive absolute savings.

If no changes were made between 2018 and 2026, we calculate that the total network opex worldwide would be almost 50% higher in 2026 than it is currently forecast to be. Opex will not, as we have already outlined, fall greatly before 2026, but the recent trend towards opex growth will have been reversed, and significant costs will have been avoided. These saved costs would amount to about USD 500 billion cumulatively between 2019 and 2026, equating to a reduction in opex intensity of over 3 percentage points (averaged across the period), and about 20% lower network opex by 2026.

The biggest impact will be seen in the RAN, where automation and sharing will reduce the average opex per site (excluding small cells) from about USD19 000 a year in 2018 to about USD11 500 by 2026. Without increased automation and sharing, we estimate that the per-site cost would fall by only about USD1500 in the same period because of more-commoditized equipment.

Opex savings in 2026 as a result of increased network sharing and automation over 2018 levels



11. Impact of shared uses of telecommunication infrastructure on telecommunication tariffs

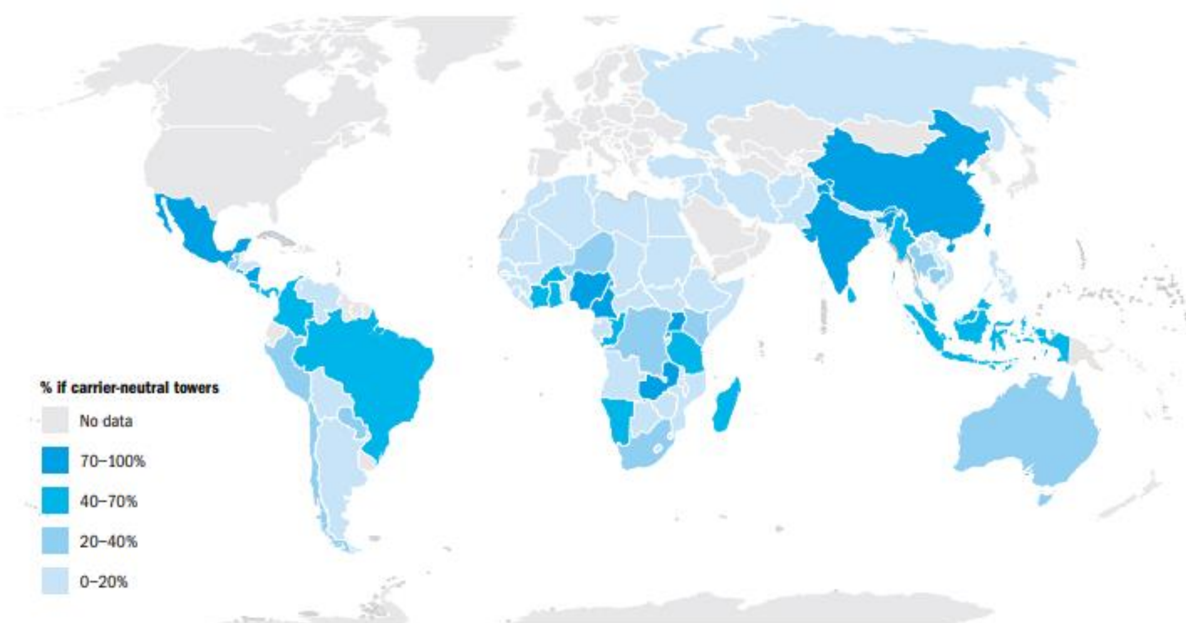
Spectrum and infrastructure sharing has a direct impact on costs, and subsequently on tariffs and investment; it may also enhance competition in the telecommunication market. Reduction of the CAPEX and operating expenditure (OPEX) due to shared uses of telecommunication infrastructure, including when enabled by aggregation of frequency bands assigned to operators who have acquired property rights over the spectrum to enable active infrastructure sharing implementation, could result in opening an opportunity for mobile operators to raising the efficiency of using the telecommunication infrastructure and making it possible for operators to reduce telecommunication tariffs for their subscribers.

As Table 1 shows, using the passive infrastructure sharing model can lead to the lowering of the telecommunication tariff by 30 per cent. Adding the active infrastructure sharing model, including Rec. ITU-T D.264 (04/2020) 5 when enabled by aggregation of frequency bands assigned to operators who have acquired property rights over the spectrum to enable active infrastructure sharing implementation, can raise the savings of customers to 50-60 per cent. Increasing opportunities for efficiency gains potentially result in increasing competitiveness and improved customer loyalty.

Table 1 – Potential savings of operators using infrastructure and spectrum sharing models

Model of shared use	Savings of operators
Passive infrastructure sharing	Up to 30%
Active infrastructure sharing, including when enabled by aggregation of frequency bands assigned to operators who have acquired property rights over the spectrum to enable active infrastructure sharing implementation	Up to 50-60%

12. Tower sharing through independent companies in selected markets[6]



[6] https://www.ifc.org/wps/wcm/connect/2d3c4eff-12a8-4b0b-b55d-9113a950ed33/EMCompass-Note-79-Digital-Infrastructure-Sharing.pdf?MOD=AJPERES&CVID=n2dwWtn

Supporting Private Investment in Shared infrastructure can be a winning model for private stakeholders, including network operators and infrastructure companies. In the mobile sector, recent data about independent tower companies across four emerging markets suggests that infrastructure sharing can be a profitable business. The estimated gross margin is close to 50 percent and the tenancy ratio, or the number of mobile operators per tower, rose from 1.3 to 1.4 one year after the beginning of operations, highlighting the increased attractiveness of the tower sharing model for mobile operators.

In India, independent tower company Bharti Infratel has a tenancy ratio close to two operators per tower with a gross margin of 44 percent.

In Africa, Helios Towers reported a tenancy ratio ranging from 1.39 in the Republic of Congo to 2.12 in Tanzania, with a 52 percent gross margin at the end of 2018.

Private operators are already active in shared infrastructure, but better public policies are needed to further drive this trend. Across emerging markets, network operators are engaging with independent infrastructure providers to share fixed and mobile broadband infrastructure using a variety of innovative business models.

Yet a lack of incentives from integrated network operators continues to limit the expansion of shared infrastructure. As in some advanced economies, public policy can promote co-investment in fiber networks by requiring all operators to share deployment plans with competitors and facilitate the use of rights of way. Although there is limited evidence from emerging markets, studies from advanced economies suggest that co-investment policies can be effective in increasing the availability of fiber-based broadband Internet access for end-users.

Regulators can also use financial incentives to support infrastructure sharing by reducing universal service requirements when voluntary sharing is undertaken with market competitors. Public policy can also help to support cross-sector infrastructure sharing. Recent examples include CEC Liquid Telecom, a joint venture between CEC, a Zambian power transmission electricity distribution company, and Liquid Telecom, a wholesale broadband provider. This joint venture enabled the provision of connectivity in Zambia, a landlocked African country, by relying on the electric grid to deploy fiber.

In more advanced economies, utilities providers like EPB in the United States, ENEL in Italy, and North power in New Zealand have set up fiber optic companies leveraged from their power distribution networks. However, many infrastructure owners still do not share due to regulatory constraints, especially for state-owned enterprises, and limited coordination across government agencies. Regulators can alleviate these constraints by refraining from offsetting sharing revenues of infrastructure owners, a practice that consists of reducing allowed revenue from core business as a result of new revenue earned from sharing. Also, a publicly available database can help operators to collect and share geographic information from projects and lead to more shared infrastructure.

Overall, infrastructure sharing will require effective regulation in order to avoid predesigned business models interfering with competitive market dynamics. In some instances, it may be desirable to enable models where the sharing of infrastructure is the result of a voluntary process and market adjustment, and not a predetermined market structure. However, regulators may need to enforce shared infrastructure where there is a market failure, for example by mandating infrastructure sharing in the context of a rural broadband connectivity program.

13. Mobile infrastructure sharing solutions brief overview[7]

Sharing Approach	Type	Details	Features	Regulatory Complexity
Site	Passive	Operators share the construction site/land used for building cell towers.	Entails sharing of costs related to leasing, acquisition of property items, contracts ,etc.	Medium
Mast	Passive	In addition to site sharing, operators share the same mast and rooftops.	Each operator has own antenna. Significant CapEx/OpEx savings.	Medium
Antenna	Active	The antenna and associated connectors (e.g. coupler, cables) are share by operators.	Passive elements such as power supply, alarms and air conditioners, fire extinguishers are share too.	Medium
Base station (BS)	Active	Operators are allocated logical "slices" of the base station.	Spectrum is either pooled or independent control is maintained.	High
Radio Network Controller (RNC)	Active	The baseband processing unit is shared by operators.	Each operator maintains independent control of the RNC virtual instance.	Low
Fronthaul	Active	Operators share the access transmission technology between the base station and RNC	This is applicable to 3G and less since 4G has RNC and BS tightly coupled.	Low
RAN	Active	Multiple core networks share RAN resources (antennas, site, BS, RNC, and transmission equipment)	Each operator is allocated a virtual RAN instance, frequency can optionally be pooled.	High (for shared spectrum)
Backhaul	Active	Multiple RANs share the transport network (e.g. optical fibre).	Backhaul sharing is most preferred in areas with limited demand.	Low
Core	Active	Core network functions such as MME and S/P–GW are share by multiple operators.	Includes sharing of MME and S/P-GW, MSC and SGSN for 4G and 3G respectively.	High
MVNO	Active	Virtual network operators lease wireless capacity from incumbent operator at wholesale prices.	MVNO resells minutes to customers.	Medium
Roaming	Active	Wireless service extension to area not covered by service provider.	Grant new entrant nationwide coverage.	High

7 http://researchspace.csir.co.za/dspace/bitstream/handle/10204/10453/Mamushiane_21273_2018.pdf?isAllowed=y&sequence=1

14. Key drivers for different types of infrastructure sharing[8]

Type of Sharing	Strategic Drivers
Passive	
Site (co-location)	• Reduced site acquisition times for new entrants • Access to locations of strategic importance, particularly where space for new sites is limited • Increased likelihood of obtaining planning permission for new sites • Reduced opex (site lease) • Expansion into previously unprofitable areas by reducing capex and opex requirements • Environmental and alleged health concerns, for example, increasing pressure from environmental groups on existing operators to reduce the number of cell sites due to health concerns
Mast (tower) times	• Reduced site acquisition and build completion • Reduced capex (site build) • Reduced environmental and visual impact
Access	
RAN coverage	• Reduced number of sites and masts for the same • Reduced capex and opex (shared physical backhaul) • Reduced environmental and visual impact
Core network	
Fibre ring	• Capex and opex saving where spare capacity
Core network elements	• Delayed investment in core network elements • Reduced maintenance and operational costs
VAS systems	• Delayed investment in VAS system elements • Increased capacity VAS systems • Enhanced capability • Reduced maintenance and operational costs
Roaming	
National	• Reduced or delayed infrastructure investment • Increased coverage
International	• Increased service coverage
Inter-system technologies	• Facilitation of the introduction of new • Seamless interoperability between operator's own separate 3G and 2G networks • Delayed investment in new technology infrastructure

15. Regulatory impact of Passive infrastructure sharing

The implementation of the passive infrastructure sharing model does not necessarily require changes to the regulatory framework. Telecommunication operators can make commercial agreements on passive infrastructure sharing in line with their respective legal framework. Member States are encouraged to consider the appropriate regulatory framework for infrastructure sharing bearing in mind the principles of minimum intervention and proportionality.

16. Regulatory impact of Active infrastructure sharing

Implementation of the active infrastructure sharing model could require some changes to the regulatory framework. Telecommunication operators can make commercial agreements on active infrastructure sharing in line with the allowance of registration of a radio system or a high frequency (HF) device for two and more operators and the rules of application for telecommunication equipment sharing RANs, for example for Global System for Mobile Communications (GSM), Universal Mobile Telecommunications System (UMTS), Long-Term Evolution (LTE). Aggregation of frequency bands assigned to operators who have acquired property

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[8] GSMA research on Mobile infrastructure sharing

rights over the spectrum to enable active infrastructure sharing implementation of active infrastructure sharing may use aggregation of frequency bands assigned to operators, who have acquired property rights over the spectrum, in order to improve network capacity and optimize RAN capital expenditure (CAPEX).

The active infrastructure sharing model could also require an enabling regulatory framework for the use of the spectrum assigned to one of the telecommunication operators by the other operators, based on the authorization from the regulator, where required, and commercial agreements between the operators.

17. Technical constraints of Infrastructure sharing [9]

The sharing of network infrastructure requires coordination and cooperation between the involved network operators, with the increase in the level of sharing. Such cooperation shall bring forth multiple constraints on the activities of the concerned operators, which ultimately limits their flexibility of operation. These constraints particularly affect the operational elements in the deployment and operation of networks and can have an impact on the ability of operators to differentiate themselves in terms of services or quality of services.

Technical constraints related to passive sharing

In the case of site sharing, the operators must take into account the following constraints:

a. The qualifying sites to share (electromagnetic compatibility, models blankets, site area, optimizing 2G 3G).

b. Installation of equipment on the shared site (access and safety, engineering site deployment schedule of operators).

c. The operation and maintenance of equipment (on-site, monitoring and steering of networking equipment).

Technical Constraints and drawbacks of active sharing

i. **Sharing of antennas**:

In case of antennas, one must consider additional constraints related to:

a. The need for common choices, affecting the quality of service (technical diversity reception and transmission, radio planning, architecture of the antenna, use of TMA (Tower Mast Head Amplifier).

b. The influence on the planning of the radio antenna amplifier linearity over several frequency bands.

[9] https://arxiv.org/ftp/arxiv/papers/1211/1211.7113.pdf

c. Taking into account in planning radio 3 dB loss induced by the coupling of the common antenna, for the separation of equipment connected to it.

ii. Sharing NodeB

In case of base stations (NodeB), we must take into account additional constraints related to:

a. The use of NodeB containing at least two carriers (a significant difference between frequency bands of operators provides additional technical complexity).

b. Limited number of operators (typically 3 or 4).

c. A risk of lead single manufacturer solutions (in particular because of the interoperability links NodeB - RNC).

d. Potential conflicts on the quality levels depending on the services available (power sharing).

e. The operation and maintenance of shared assets.

iii. Sharing the RNC

In case of sharing of base stations controllers (RNC), we need to take into account the same types of constraints for sharing the Node B, which are still relevant in the case of the RNC, and additional constraints related to:

a. Management of separation of the RNC functions (radio access configuration, performance management and quality of radio services)

b. Interoperability between equipment from different manufacturers (hardware and software configuration)

c. Interoperability between RNC and shared RNC to ensure the handover (soft handover).

iv. Core network sharing

In case of equality of elements in the core network, it must take into account additional constraints related to:

a. A choice of design of equipment common (NodeB, RNC, MSC, SGSN) to handle the traffic associated with the provision of services of each operator

b. A design package from core network management and service quality

c. The need to support intelligent network protocols consistent to ensure continuity of customer service of each operator when roaming on the shared network.

The sharing of sites and antennas, a combination of level one and level two sharing, can reduce on an average 20-30% of CAPEX costs. If the operators also share the radio network, there can be more savings, whereby the operators can save between 25 and 45%. Finally, the sharing of all the assets would decrease CAPEX by an additional 10%.

18. Barriers to increase infrastructure sharing[10]

a. Insufficient space on existing masts- In many cases, it is hardly possible to install additional equipment. This is not only a result from a lack of space, but also due to an increased energy consumption caused by the additional equipment. The installation of additional antennas can be problematic due to the length restriction of poles and masts. Poles on rooftops are even more limited in length.

b. Landlord Pricing- The need for more space at sites and the leasing of new sites leads more likely to additional agreements with landlords and therefore potentially to higher rental costs.

c. EMF restrictions- Against the backdrop of barriers, another issue identified by the contributors is the Electro Magnetic Radiation (EMR). For example, in Poland the level of admissible electromagnetic radiation is 0.1 V/m2 and is seen as a possible barrier for infrastructure sharing. In addition, Switzerland stated that the threshold for non-ionizing radiation could be an obstacle for sharing infrastructure. To sum it up, public concern regarding EMR should not be underestimated while assessing barriers (Norway).

d. Administrative processes- This includes permits of civil works (Bulgaria, Denmark), slow processing of building permits (Belgium, Denmark), local taxes for antennas and pylons (especially in the Brussels communes and Walloon provinces, Belgium) and the access granting to (private) large premises (Malta, Norway). At least Greece stated that also the licensing period per site could be a burden.

e. Coordination effort- As already stated above with regard to negative experiences concerning infrastructure sharing, the coordination effort is also seen as a potential barrier. With a view to the 5G rollout as mentioned before, it is expected that a much larger amount of sites will be needed. As the amount of sites increases, also the number of sharing agreements is expected to increase or at least the complexity of such agreements to become higher. In addition, Netherland stated that the network planning is MNO specific. This means that the existence of a site of one operator may be irrelevant for the network optimization of another operator. In the context of network planning, other issues regarding potential barriers to increase infrastructure sharing is raised by some respondents.

[10] BEREC Report

f. Technical issues- Infrastructure sharing usually requires the same technical standards which are often ensured due to network equipment from one vendor. As not all MNOs use the same network supplier or make use of different technologies/protocols, this can also cause technical difficulties and thus needs close cooperation.

19. What is a NetCo?[11]

NetCo is a shared network model where a third party or operators jointly establish a separate entity, like a joint venture, to build and/or operate a shared network. In 3G and 4G network sharing, especially in the form of a NetCo, is widely seen as an effective way to accelerate network deployment, while reducing network-related investment and operational costs. For example, MBNL, the network sharing joint venture between UK operators EE and 3, has significantly improved 3G coverage, generated £1 billion in savings over 10 years and helped operators capture market share.

20. Why NetCos for 5G? Why now?

5G is happening now and operators are trying to find optimal ways to successfully roll-out. Network sharing can deliver significant economic and operational benefits, including:

- Up to 40% savings in deployment CAPEX/OPEX from cost reduction in small cells roll-out, macro cell and core upgrades and 5G spectrum.
- Faster deployment time.
- Significant operational efficiencies (e.g. spectrum efficiency, network operations) and cost savings in the long term.
- Better network experience for consumers through increased footprint and/or capacity.
- Reduction of risk of redundant / unprofitable investments.
- Maintaining retail competition, ensuring fair prices for consumers.

What does it mean for operators and policy makers?

A NetCo for 5G rollout sounds attractive but it requires significant effort and alignment from regulatory authorities and telcos.

Telecom and competition authorities may need to reconsider their infrastructure regulations, spectrum policies, industry fees, incentives and competition policies to allow sufficient sharing by operators while maintaining a healthy level of market competition, QoS and prices.

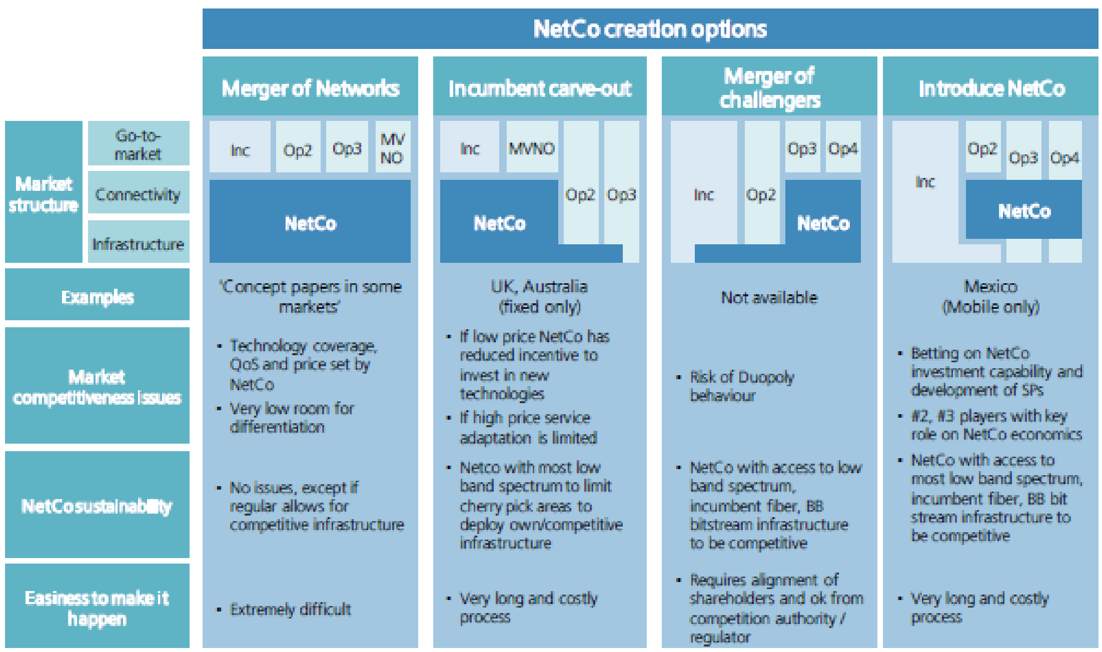
For telcos exploring a NetCo model, it is essential to understand the complexity of 5G deployment, with paramount importance placed on a well-planned execution strategy. Moreover, a significant

[11] Delta Prospective report on 5G Network Sharing

degree of alignment is required from all involved parties, especially on key issues such as financial agreements and vendor selection.

The creation of a NetCo can take different forms: **A merger of all market networks; an incumbent network carve-out; a merger of challengers' networks; or the introduction of an independent NetCo**.

The key drivers determining the final model will be dependent on the current market situation, telcos' willingness to reach an agreement and regulatory flexibility. Each model offers different challenges and risks deployment more efficiently and at lower costs. All the while, regulators must examine current network sharing related regulations, including spectrum policies, and facilitate NetCos as part of the national 5G strategy.



21. Indian Telecom Scenario[12]

Currently, India is the world's second-largest telecommunications market with a subscriber base of 1.16 billion and has registered strong growth in the last decade.

12 https://www.ibef.org/industry/telecommunications.aspx#:~:text=Indian%20Telecommunications%20Industry%20Report%20(Size,KB%20)%20(October%2C%202020)&text=Currently%2C%20India%20is%20the%20world's,growth%20in%20the%20last%20decade.

a. Market Size

India ranks as the world's second largest market in terms of total internet users. The number of internet subscribers in the country increased at a CAGR of 21.36% from FY16 to FY20 to reach 743.19 million in FY20. Total wireless data usage in India grew 9.35% quarterly to reach 22,854,131 TB in Q4 FY20.

India is also the world's second-largest telecommunications market. Its total telephone subscriber base and tele-density reached 1,177.97 million and 87.37%, respectively, in FY20.

Gross revenue of the telecom sector stood at Rs. 252,825 crore (US$ 35.87 billion) in FY20.

Over the next five years, rise in mobile-phone penetration and decline in data costs will add 500 million new internet users in India, creating opportunities for new businesses.
The Government of India planned to roll out a new National Telecom Policy 2018 in lieu of rapid technological advancement in the sector over the past few years. The policy intended to attract investments worth US$ 100 billion in the sector by 2022.

In India, spectrum sharing will be restricted to sharing by only two licensees subject to the condition that there will be at least two independent networks provided in the same band. Spectrum Usage Charges (SUC) rate of each of the licensees post-sharing shall increase by 0.5 percent of Aggregate Gross Revenue (AGR).

b. Current scenario

The Indian telecom sector was among the first to adopt passive infrastructure sharing in a big way. TSPs shared the passive infrastructure with their peers that led to significant savings.

Meanwhile, active infrastructure sharing including antennas, feeder cables, Node B, RAN and transmission systems, was allowed to the TSPs by DoT in February 2016. However, adoption of active Infrastructure sharing has been slow.

One of the major reasons for the slow adoption is that the payment made by one TSP to another TSP for the sharing of the active Infrastructure has not been allowed as a pass through by the Government.

Step that can be taken to facilitate active Infrastructure sharing:

1. Pass through should be allowed for any consideration paid by one TSP to another for active infrastructure sharing.

2. Allow sharing of Core network elements.

India's telecom sector, in the efforts of enabling policies including more quantum of the spectrum, is set to establish new benchmarks in the next-generation network deployments and service delivery.

Currently, infrastructure firms can provide assets such as dark fibers, towers, duct space and right-of-way only to the telecom operators on non-discriminatory sharing basis.

By way of adopting active sharing, the deployment of government programs such as Digital India, Smart Cities, financial inclusion, and rollout of fifth-generation (5G) networks would become easier.

At the global level, the conventional wisdom is that infrastructure, both active and passive, needs to be shared to ensure better spectral efficiency, better quality of service (QoS) delivery and reduced capital expenditures. Global telecom stakeholders have been vouching for policy initiatives that incentivize and promote infrastructure sharing. In this regard, India's National Digital Communications Policy, 2018 envisages enhancing the scope of infrastructure providers to enable universal broadband access.

c. Key benefits

Infrastructure sharing tends to impact coverage, QoS and pricing of services to consumers. It may lead to efficient and positive outcomes such as:

a. Decrease in the duplication of investment, which tends to reduce costs for operators and prices for consumers.

b. Reduction in the cost of providing services to underserved areas.
c. Improvement in QoS delivery due to increase in network coverage and capacity.

d. Enabling operators to compete on service innovation and technology rather than solely on coverage.

e. Benefiting consumers by increasing the choice of providers as entry and expansion becomes easier and speedier through network sharing.

22. Why infrastructure sharing in India is most important?

a. Currently, the growth of data consumption in India is primarily driven by mobile networks. However, this growth has limitations like spectrum availability constraints and non-availability of optical fibre in access backhaul networks due to which base stations work on microwave backhaul transmission links that have capacity limitations.

b. As the Indian telecom market steps into the 5G era, the use of higher frequency bands and deployment of small cells will become the new norm. This will result in the evolution of integrated networks called HetNet (heterogeneous network) consisting of macro cells, micro/small cells and Wi-Fi access points. However, fiberisation of these integrated networks by each TSP in the non-sharing mode would be quite costly and a time-consuming process.

c. In this scenario, sharing of active infrastructure seems to be the ideal solution, especially when technological advancements have made it possible to share antennas, feeder cables, base-band units and transmission systems by multiple mobile service providers while still using their own assigned spectrum.

d. The QoS and other operating parameters can also be maintained separately by each mobile service provider. Additionally, the sharing of access networks could facilitate provisioning of telecom services at affordable prices in some remote and less accessible areas.

e. Moreover, sharing of active infrastructure could play a big role in scaling up the abysmally low penetration of wireline broadband services in the country. A simple perusal of the performance indicators published by TRAI indicates that the primary focus of the TSPs operating in India is on wireless access services. This trend could be attributed, in part, to higher efforts required for provisioning and maintenance of wireline access services. In this regard, the availability of shared WAN in a non-discriminatory manner may encourage local entrepreneurs to start provisioning wireline broadband services in their area of operations and help improve India's wireline broadband penetration.

23. International Benchmarks[13]

Policy-makers and regulators are examining the role that mobile network sharing can play in increasing access to information and communication technologies. The focus is on how this could generate economic growth, improve quality of life and help developing and developed countries to meet the objectives of the World Summit on the Information Society and the Millennium Development Goals established by the United Nations.

Here are some examples of what is happening in mobile infrastructure sharing around the globe.

i. Spain and the United Kingdom

Most European countries promote the sharing of passive infrastructure by mobile operators. Given the high cost of obtaining 3G (IMT-2000) licences, many European operators have also been considering sharing active infrastructure for 3G mobile services. An example is the agreement between Orange and Vodafone to share infrastructure in the United Kingdom and in Spain, while managing their own traffic independently and remaining competitors at the wholesale and retail

[13] https://www.itu.int/itunews/manager/display.asp?lang=en&year=2008&issue=02&ipage=sharingInfrastructure-mobile

level. According to Vodafone, the UK sharing agreement will reduce capital and operating costs by up to 30 per cent.

In Spain, the arrangement will reduce the operators' number of sites by around 40 per cent, while offering services to towns across the country with fewer than 25 000 inhabitants. The agreement also allows for 3G wireless services to be provided to 19 provinces in rural areas of Spain.

ii. Brazil

At the beginning of 2008, the Brazilian government issued 44 licences for the provision of 3G mobile services. Four operators were licensed in each of 11 licensing areas with a total population of 17.3 million. Regulator ANATEL took measures to ensure that communities with fewer than 30 000 inhabitants (a large percentage of the total) would receive wireless broadband coverage. In each area, the total number of such communities was divided equally among the four licensed operators, who must offer them access to broadband. All the operators in an area are allowed to use each other's networks to provide services. ANATEL intends that the whole country should have access to wireless broadband services by 2016.

iii. Jordan

In Jordan, all mobile telephony licensees are required to provide infrastructure sharing and collocation to other licensees, subject to availability. Jordan's Telecommunications Regulatory Commission (TRC) reserves the right to intervene if mobile companies fail to reach agreement on infrastructure sharing and national roaming. When TRC determines that infrastructure sharing is feasible, it decides the terms and conditions under which this must take place. Operators must also provide each other with national roaming agreements, which must be deposited with TRC.

iv. Canada

In Canada, the government has announced a policy of auctioning advance wireless services (AWS) radio spectrum in the 2 GHz band. It will reserve part of the newly auctioned spectrum for new market entrants, and will make network sharing compulsory. Incumbents are required to provide "out of territory" roaming capabilities to licensees for at least 10 years, and "in-territory roaming" to new entrants for five years. The new framework also includes mandatory sharing of antenna towers and infrastructure sites, and the prohibition of most exclusive site sharing arrangements.

v. Malaysia

The Malaysian Communications and Multimedia Commission (MCMC) has identified infrastructure sharing as one of the criteria for issuing licences for 3G mobile spectrum. Applicants must show that they can and will share infrastructure, including physical facilities and network capacity. The aim is to maximize use of existing network resources, including capacity, base stations and backbone facilities. Applicants must also be committed and able to provide domestic roaming.

vi. Nepal

In Nepal, to regularize the construction and use of telecommunications infrastructure and to make the telecommunications service affordable & easily available through the sharing of telecommunications infrastructure and thus bringing about a reduction of investment in the telecommunications infrastructure with anticipation of lowering the service user charge Government of Nepal promulgate the Telecommunications Infrastructure Regulation, 2074 (2017) and published a notice for Request For Applications (RFA) for a License to Provide Telecommunications Infrastructure Services in Nepal. **However, Service Provider cannot share any Active Infrastructure.**

vii. Pakistan

In Pakistan, Cellular Policy 2004 encourages passive infrastructure sharing and the same concept was included in the mobile licenses as well. However, active sharing was not considered then. Telecommunication Policy 2015 highlights **passive as well as active infrastructure sharing** for which regulations and guidelines will be prepared in the light of best international practises.

viii. Sri Lanka

As per the guidelines issued by Telecommunications Regulatory Commission of Sri Lanka14 in October 2017, to minimise the adverse impact to the aesthetic appearance and vegetation, it is encouraged to co-locate antenna structures erected by the TSPs. Telecommunications Regulatory Commission of Sri Lanka (TRCSL) should identify such locations which are named as Antenna Structure Farms (ASFs). TSPs may propose such locations to TRCSL. Antenna Structures of height more than 30m ground based and the total height more than 30m on roof top, excluding 5m poles, shall be used on shared basis. Hence the antenna structures shall be designed and constructed to accommodate the requirements of two other TSPs. Earlier in July 2009, TRCSL had issued a guidelines as per which Antenna Structures should be designed and constructed with provisions for more than one service provider. Such constructions are encouraged through incentive schemes.

ix. Netherlands

In the Netherlands, NMa (Netherlands Competition Authority), OPTA (Independent Post and Telecommunications Authority), and the V& W(Ministry of Transport, Public Networks and Water management) issued a joint memorandum that provided comprehensive clarification on collaboration in the deployment of 3G networks in September 2001. They agreed to allow 3G service providers to collaborate in the construction of 3G network components on the condition that competition between service providers continued to exist and that service providers compete

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[14] Guidelines on Antenna Structures Based on the National Policy on Antenna Structures : http://www.trc.gov.lk/images/pdf/guide_l.pdf

against one another in providing 3G services. While they shared the opinion that collaboration in 3G network deployment could contribute to a more rapid 3G roll-out, they clarified that collaboration must be limited to the joint construction and use of the 3G network infrastructures such as masts, aerials and network operation. **On this basis, they did not permit the joint use of frequencies and core networks.**

x. Finland

Ministry of Transport and Communications monitors the development of 3G mobile networks and services and made proposals on the commercial opening of networks and possible coverage requirements by 30 November 2004. Since this change, commercial agreements on mast sharing, network sharing and national roaming have been signed in Finland. The regulator has the power to step in should commercial arrangements be agreed on a timely basis between operators. These agreements have also been seen in the 2G environment, for example Telia Mobile signed a national roaming agreement with Suomen 2G. They have also led to establishment of a number of MVNOs, since operators are permitted to share 65% of their networks.

xi. Australia

The Regulator appears to actively support site and mast sharing and has permitted a number of operators to share radio access networks**. However, sharing of core networks does not appear to be actively encouraged.**

xii. Canada

In Canada, the government has announced a policy of auctioning advance wireless services (AWS) radio spectrum in the 2GHz band which makes network sharing compulsory.

The new framework also includes mandatory sharing of antenna towers and infrastructure sites, and the **prohibition of most exclusive site sharing arrangements.**

24. Publication of information about infrastructure sharing opportunities[15]

Operators are obliged to publish information on passive infrastructure sharing opportunities in advance, in a public forum, in nine countries **(Belgium, Bulgaria, Croatia, Greece, Italy, Latvia, Liechtenstein, Montenegro and Serbia)**.

In Norway, the obligation applies only to the SMP operator. The obligations can take the form of online publication, notifying the NRA/Ministry or publication via a third party platform.

In some countries, although there is not a regulated approach that mandates operators to publish sharing opportunities, information regarding cell site location is available through either privately organized databases/structures or NRA managed portals. For example, there are privately

[15] BEREC report

organized databases/structures in Austria and the Netherlands. In the Netherlands, this is complemented by a requirement that mobile operators must coordinate site planning to minimize environmental disruption to local communities.

A similar requirement exists in France that requires operators to consult other operators to gauge their interest when deploying new sites (excluding dense areas).

Following the transposition of the broadband cost reduction directive (BCRD) most countries have a general passive infrastructure sharing obligation, although this does not translate into a requirement for publication of information on infrastructure locations or deployment plans in a number of countries **(Czech Republic, Finland, Germany2, Hungary, Malta, Poland, Romania, Slovenia, Spain, Sweden, Switzerland and Turkey).**

In Bulgaria, Finland and Italy, there is a Single Information Point (SIP) in accordance with the requirements of the BCRD that provides information on the location of physical infrastructure that can be used for infrastructure sharing.

25. Regulatory approval for infrastructure sharing overview[16]

[16] https://www.gsma.com/publicpolicy/wp-content/uploads/2012/09/Mobile-Infrastructure-sharing.pdf

Country	Has sharing been mandated	Has sharing been approved	Differentaited approach to national roaming depending on geographic area
Australia		✓ Regulator is supportive. ✓ RAN Sharing is permitted	
Austria	Antenna Mast and powerline masts must be shared if technically feasible , in particular in relation to frequencies	✓ Only for 3G networks and limited in clarification and by coverage agreements.	
Denmark	X	✓ Regulator is supportive of some forms but not others.	
Finland		✓ Subject to meeting minimum license requirement.	Regulated for 3G on 2G
Germany	X	✓ National roaming, time limited ✓ Limited RAN Sharing	✓ Roaming in urban areas to be phsed out before roaming in rural areas.
HongKong	Can be directed to share if in the public interest or commercial negotiation breakdown		
India		✓	X
Itlay		✓ Regulator is monitoring the situation	
Jordan	Regulator only intervene if commercial negotiation fails	✓	
Netherland	X	✓	X
Nigeria	✓	✓	X
Norway	✓ Telenor obliged to provide national roaming.	✓	X
Pakistan	X	✓ Some forms of sharing (site and masts) are actively encouraged. Other forms are under consultation.	X
Spain	X	✓	
Sweden	✓ Regulator ocassionally intervene if commercial negotiation fails	✓ Shared 3G network which serves 70% of the population has been permitted	
UK	X	✓ National roaming,time limited ✓ RAN sharing announced	✓ Roaming in urban areas to be phsed out before roaming in rural areas.

List of Acronyms

S.No.	Acronym	Description
1	HDTV	high-definition television
2	P2P	peer-to-peer
3	PCs	personal computers
4	QoS	Quality of Service
5	UMTS	Universal Mobile Telecommunications Service
6	NFV	Network Function Virtualization
7	SDN	Software Defined Networking
8	RAN	Radio Access Network
9	HLR	Home location register
10	VAS	Value Added Systems
11	EIR	Equipment identity register
12	MORAN	Multi-operator RAN
13	MOCN	Multi-operator core network
14	NMO	Network mode of operation
15	GWCN	Gateway core network
16	TMA	Tower Mast Head Amplifier
17	SBT	Smart Bias Tee
18	RRH	Remote Radio Head
19	opex	Operational expenditure
20	MNO	Mobile Network Operator
21	TCO	Total cost of ownership
22	CAGR	Compound Annual Growth Rate
23	CAPEX	Capital expenditure
24	EPB	Electric Power Board of Chattanooga
25	ENEL	Ente nazionale per l'energia elettrica
26	CEC	Copperbelt Energy Corporation
27	BS	Base Station
28	RNC	Radio Network controller
29	GSM	Global System for Mobile Communications
30	HF	high frequency
31	LTE	Long-Term Evolution
32	EMR	Electro Magnetic Radiation
33	EMF	Electro Magnetic Field
34	SUC	Spectrum Usage Charges
35	AGR	Aggregate Gross Revenue
36	HetNet	Heterogeneous network
37	WAN	Wide Area Network
38	AWS	Advance wireless services
39	MCMC	Malaysian Communications and Multimedia Commission
40	RFA	Request For Applications
41	TRCSL	Telecommunications Regulatory Commission of Sri Lanka
42	SIP	Single Information Point

Thank You