

Ercole, Roberto

Conference Paper

Regional Roadmap – Accelerating Terrestrial 5G Deployment

2nd Europe - Middle East - North African Regional Conference of the International Telecommunications Society (ITS): "Leveraging Technologies For Growth", Aswan, Egypt, 18th-21st February, 2019

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Ercole, Roberto (2019) : Regional Roadmap – Accelerating Terrestrial 5G Deployment, 2nd Europe - Middle East - North African Regional Conference of the International Telecommunications Society (ITS): "Leveraging Technologies For Growth", Aswan, Egypt, 18th-21st February, 2019, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/201739>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Regional Roadmap – Accelerating Terrestrial 5G Deployment

Roberto Ercole <https://www.linkedin.com/in/roberto-ercole-1158771/>

Spectrum Telecoms and Consulting Ltd. Cambridge UK

Rercole99@gmail.com

Abstract

The overarching question this paper is trying to address is: *“Can we rely on market forces and competition to deliver 5G the way it delivered GSM, 3G, and 4G, or do we need another approach?”*.

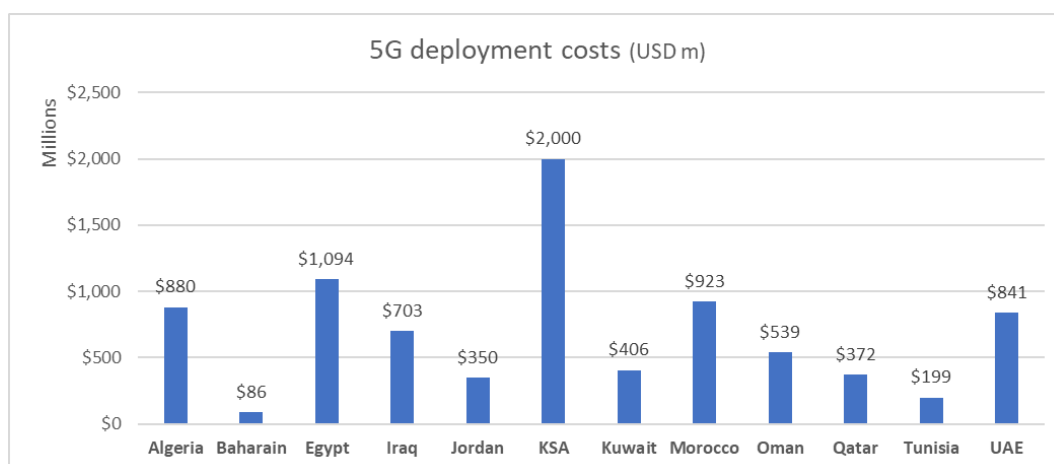
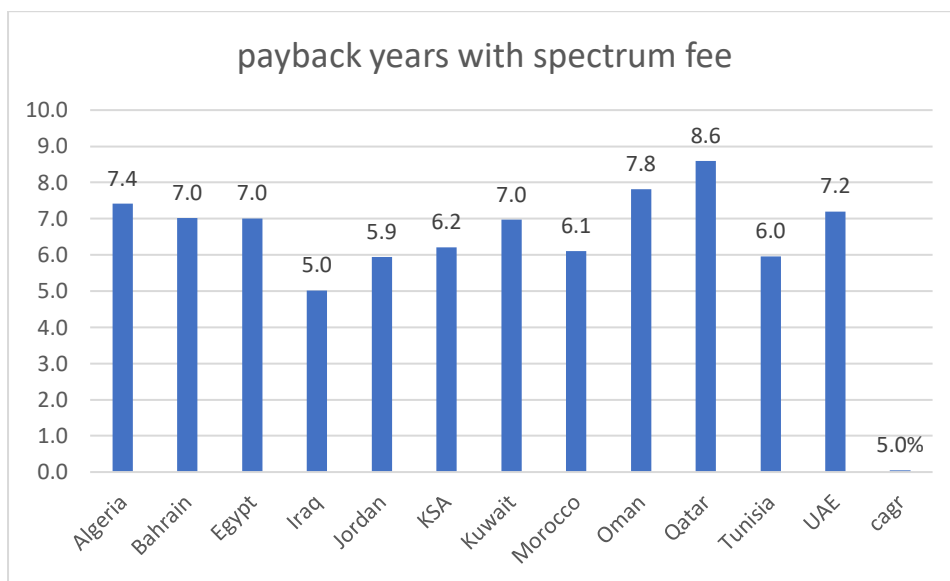
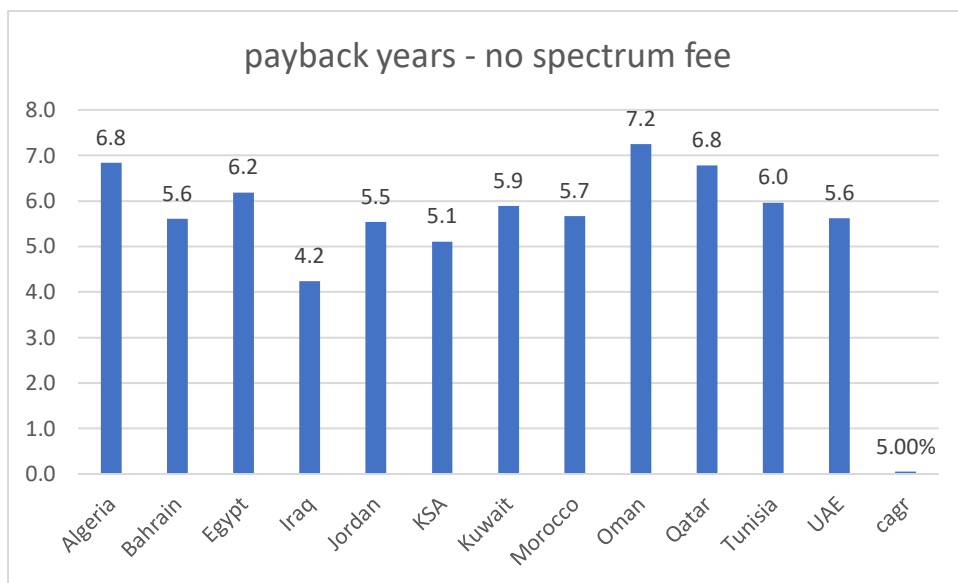
The metric used in the paper is payback period, which while it is not an economically “rigorous” method, it does resonate with some industry decision makers. It could be considered the first hurdle any investment proposal needs to clear before progressing to say a detailed NPV analysis. The impact of various assumptions is explored in the costs and payback figures.

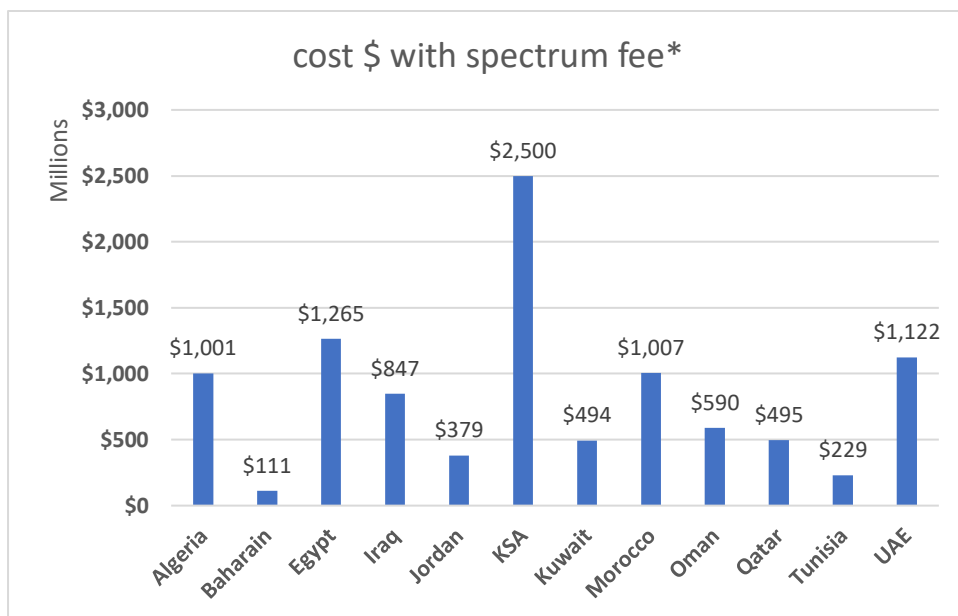
The paper is not an economic analysis but an industry participant’s view and examines what might influence industry players who will take the risks with large capital investments running into \$100’s million in many markets. The author believes that only the current mobile opcos in the region are likely to make the investments to deliver wide area 5G (as opposed to very isolated hot-spot coverage). Therefore, it is important to understand how mobile opcos and their investors might perceive 5G. The lack of faith in the 5G business model from some in the industry is not a good sign.

The paper also looks at what regulators might do (if they wish to encourage 5G) to speed up deployment of 5G. Regulatory measures might be consideration on spectrum licence fees or other taxation on mobile, as well as considering the number of operators who cover rural areas. Other issues that can help will be the reduction of regulatory uncertainty due to international radio cross-border interference -which may be an issue in the region for new 5G bands.

This paper follows on from the paper written by the author and delivered at the SAMENA Leaders’ Summit in May 18, but is the view of the author alone, and not of SAMENA.

Results





**assuming KSA Jan. 19 auction benchmark*

Discussion of Results

The results of this bottom-up approach, compared to the original paper, show lower 5G deployment costs (except for Oman). It should be noted that the May 18 paper did not consider spectrum fees. For example, the KSA figure was \$3752m, whilst Algeria was \$2474m, and UAE was \$1298m (May 18). In general (noting variations from 1.4 to 3.5) the deployment costs found using this bottom-up approach were about half the costs of the May 18 paper (on average).

The payback years with no spectrum fee range from around 5 to 7 years, excluding Iraq. As is noted in the paper, Iraq's lack of 4G deployment will increase its 5G deployment costs by around \$660m. An increase can also be expected for Egypt for the same reason.

With the spectrum fees included (and again ignoring Iraq) we can see an increase to give a payback range from 6 to nearly 9 years. As was discussed below the spectrum benchmark chosen (KSA January 19) was probably a benign one, but still increased KSA's costs by 25%. If much higher spectrum fees are used, then the payback will obviously be increased.

One major issue is the assumption of what we mean by 5G deployment. If it is only for very dense urban areas, then the costs will be much less, but might for example with Egypt mean reducing coverage from 8% of landmass to say 0.5% of landmass (or less). One would expect the more limited the 5G coverage (relying on 4G instead) the less the revenue uplift from 5G (assumed at 5% CAGR). Hence whilst the deployments costs would reduce, all other things being equal, so would the increase in revenue.

In absolute terms a payback of 5 years may be acceptable (depending on perceived risks) but moving to above 8 might be marginal (in the author's opinion). Anything above 10 would seem an unlikely business proposition. The spectrum fees assumed are much less than in some awards, so a big push in such fees will increase these paybacks.

Background

This paper looks at what the costs and revenues of 5G deployment might be in the MENA region based on certain assumptions. These assumptions should not be taken as “given” but are intended to represent a starting point for discussion. The purpose is to help regulators understand the cost implications of 5G and perhaps develop a framework with their local operators to further explore these issues. Even if the assumptions are inaccurate, it is hoped such a framework can at least help focus discussions on the key issues for a market – and perhaps show the sensitivity of a business plan to certain regulatory actions.

This paper further develops issues discussed in a paper¹ presented by the author at the SAMENA Leaders’ Summit in May 18². That SAMENA paper looked at the costs based on a flat fee per subscriber based on an EU study (by Real Wireless and Trinity College Dublin³). The May 18 paper used assumptions (such as relative GDP per capita) to derive 5G deployment costs in the MENA region. However, it was very much a top-down model using implicit assumptions about European networks – such as quality and coverage. The author believes that the costs of deploying 5G are sensitive to assumptions such as the level of 4G deployment in a market.

One of the issues this paper tries to raise is that whilst there has been much discussion of the potential benefits from 5G for the wider economy, there has been very little focus on what part of this benefit will be captured by the mobile networks – they need to make the investments. The author found very little on what is the operators’ share of such economic benefits. Even if the economic benefits are high, if no one is prepared to risk the investments they won’t happen.

The paper also shows that spectrum fees are non-trivial and can have a significant impact on payback periods. Using the recent KSA auction suggested that spectrum fees might be around 25% of costs. That is increasing KSA deployment costs from \$2,000 to \$2,500 million. The average increase in deployment costs for the countries studied was 20%.

It may be that (very limited hotspot 5G coverage aside) we are approaching the limits of what commercial networks can provide. This is assuming the relatively weak incremental 5G revenue projected for mobile operators. Indeed the 5% CAGR predicted (at best) may not be that attractive an investment compared to a US Treasury Bond of around 3%, when the risks are compared.

Even the report by the ITU on 5G highlights the industry scepticism and challenges with the business case⁴. With a more interventionist approach, such as lower spectrum fees or allowing not just mast sharing but having a common network in rural areas (say) then the promise of 5G will perhaps be easier to realise in the next 5 years.

Introduction

The introduction of 5G services is a major topic with a number of regulators around the world and in the MENA region as well. Regulators wish to see the commercial deployment of 5G beginning this year and have made suitable spectrum available. UAE, Saudi Arabia, and Oman have recently

¹ <https://www.slideshare.net/RobertoErcole/ls-18-5-g-white-paper-final>

² <https://www.samenacouncil.org/ls2018/>

³ <https://ec.europa.eu/digital-single-market/en/news/5g-deployment-could-bring-millions-jobs-and-billions-euros-benefits-study-finds>

⁴ https://www.itu.int/en/ITU-D/Documents/ITU_5G_REPORT-2018.pdf

announced spectrum awards for the commercial deployment of 5G⁵, after allowing pre-commercial trials. The figure below shows that a number of GCC countries are launching commercially this year, closely followed by other MENA countries.

Commercial launch of 5G mobile services in MENA



Figure 1 - source: GSMA – 5G in MENA

GSMA predicts 16% penetration for 5G (excluding IOT and fixed wireless) by the end of 2025 for GCC countries, and 6% for the MENA region as a whole⁶. This bodes well for the strategic commitment of operators and governments in the MENA region to make 5G a strategic priority. According to the World Economic Forum⁷:

“Developing nations have rivalled or surpassed their industrialised counterparts in benefiting from the deployment of mobile technology, and there’s every reason to think 5G will have an even bigger levelling effect than its predecessors.”

Economists estimate the global economic impact of 5G in new goods and services [will reach \\$12 trillion by 2035](#) as 5G moves mobile technology from connecting people to people and information, towards connecting people to everything.”

But some have questioned this belief in 5G in the mobile industry, and there are many who wonder about the commercial case for it. There are also more negative views about future mobile investments in broadband as being a “*race to the bottom*” to capture market share at ever lower prices⁸. There needs to be an economic case for investing the huge sums necessary to develop and deploy 5G, and the question will be what extra revenue will it give me over 4G? Not all agree this is a given (for example see “*The 5G Myth*” by William Webb on Kindle).

⁵ <https://www.telegeography.com/products/commsupdate/articles/2018/02/12/citc-awards-additional-spectrum-to-stc-zain-and-mobily/>

⁶ <https://www.gsmaintelligence.com/research/?file=41a57dc7d3baad611133be7deb481930&download>

⁷ <https://www.weforum.org/agenda/2018/01/the-world-is-about-to-become-even-more-interconnected-here-s-how/>

⁸ <https://www.strategyanalytics.com/strategy-analytics/news/strategy-analytics-press-releases/strategy-analytics-press-release/2015/01/23/global-trends-for-mobile-operators-show-stagnant-revenues-and-declining-margins#.WFGGoXXJpx>

Even the UN/ITU has issued a “caution”, saying there is concern that 5G maybe “premature”, and that operators are “sceptical about the commercial case”⁹. The ITU report suggests that the business case for rural and suburban areas is “challenging”, which could potentially widen the digital divide. But if 5G is only for “densely populated areas” this makes it geographic availability less than 1% of landmass (see table 1).

The ITU report also adds the caveat that fibre backhaul must be feasible - even to cater for this small geographic market of dense urban. One might use fixed broadband penetration as a proxy for fibre backhaul availability. Figure 2 below shows broadband penetration is low in most MENA markets compared to Germany and the UK.

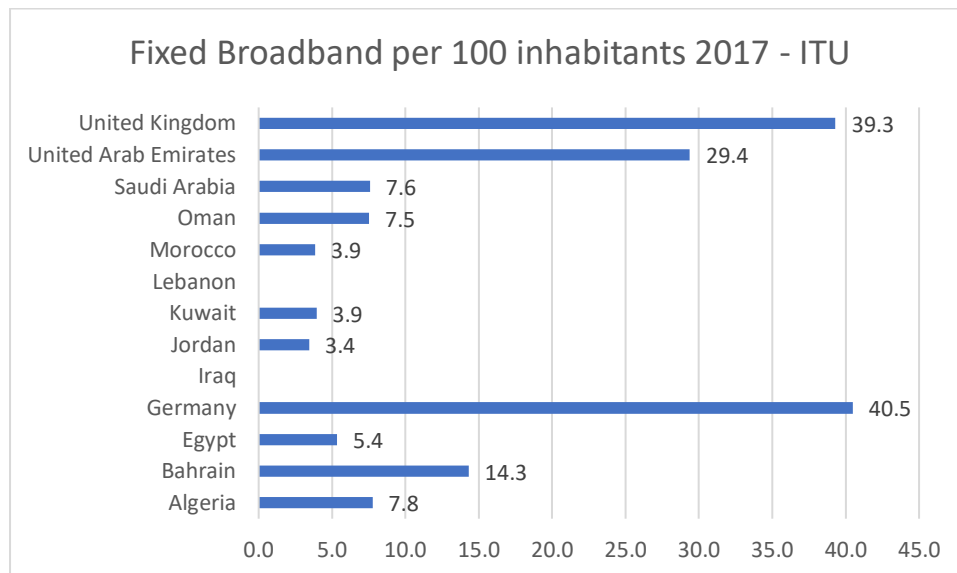


Figure 2

The experiences of 3G (and the high spectrum fees paid) and the financial turmoil of 2010 have made the industry much warier about such claims. Even if the big numbers on global economic impact are correct, how much will mobile operators capture? Over-the-top (OTT) media services such as Facebook with *WhatsApp* and Apple *FaceTime*, have meant that the old mainstay of mobile revenue (voice and SMS) are no longer viable in the long term, as major revenue streams. The fear is that in the new 5G environment mobile operators could see their relatively flat revenues decline.

It must be remembered that while the economic benefits to the economy may be much larger (indeed should be), what matters for operator investment appraisal, is how much will flow to the opcos. As has been discussed above the move from voice and SMS centric revenues to data revenues has seen Over The Top (OTT) services effectively cannibalise opco revenue. For example, WhatsApp, giving away voice and SMS makes it hard for mobile opcos to charge for what OTTs give away for free.

Relying on pure market forces to deliver a wide area 5G network, based on the move from 3G to 4G may not be the best way. Looking back, the choice between 3G and 4G/LTE was much clearer in terms of capabilities. For example, OpenSignal¹⁰ reports average download speeds of 3G and

⁹ https://www.itu.int/en/ITU-D/Documents/ITU_5G_REPORT-2018.pdf

¹⁰ <https://opensignal.com/reports/2018/02/state-of-lte>

4G/LTE and Wi-Fi. It finds that in February 18, 3G has an average download speed of 4.1 Mbps, whilst WIFI's is 14.0 Mbps, but 4G/LTE is 16.9 Mbps (in the 88 countries measured).

The danger is that with such scepticism in the market (from respected sources such as the ITU), commercial drivers might deliver only very limited 5G deployment in dense urban areas. This might amount to less than 1% of landmass of a country (depending on demographic analysis). Table 1 (below) gives the demographics for some European countries. This shows just how limited and hotspot urban deployment might be in geographic terms.

country	Hotspot + dense urban + urban (km ²)	% total landmass	Population density per km ²
UK	2,399	0.986%	263
Sweden	282	0.063%	22
Hungary	165	0.177%	105
Italy	2,039	0.66%	196

Source: Plum, "Use of C Band for mobile in Hungary, Italy, Sweden and the UK" – June 2015

Table 1

The population density of Egypt is around 100 people per km². Most the countries considered in this paper sit somewhere in the population density range in table 1 – except for Bahrain with around 1,900 per km². If we are to assume 5G will only be available at best in 1% of the landmass then that must question the economic benefits some have suggested.

If that is the case, then from a consumer perspective what is being deployed seems very similar to Wi-Fi – which has very limited incremental revenue opportunities for opcos.

Geographic Coverage

One of the main assets a mobile network has over competitors using Wi-Fi or other shared spectrum bands (normally), is the quality of service they can offer, and the large geographic area or percentage of the population covered. The exclusivity of their spectrum licence allows the opco to guarantee a level of coverage and data throughput that consumers and business customers value. It can also be argued that this exclusive spectrum licence is the asset that opcos need to raise the money they need to invest in their networks.

The level of investment the opcos make in their networks can be seen in their base station numbers (see figure 5) - with nearly 23,000 sites in Egypt alone. The capex and opex for each operator are vast to not only maintain but upgrade these networks regularly with extra sites for improved coverage and capacity; they also invest in new technologies every 10 years or so (sooner in the case of 5G).

Operators in the MENA region are also faced by the challenge of trying to increase geographical coverage (even on 3G in some cases). For example, Egypt's population coverage for 3G/4G mobile is shown below (noting 4G is LTE and WiMAX).

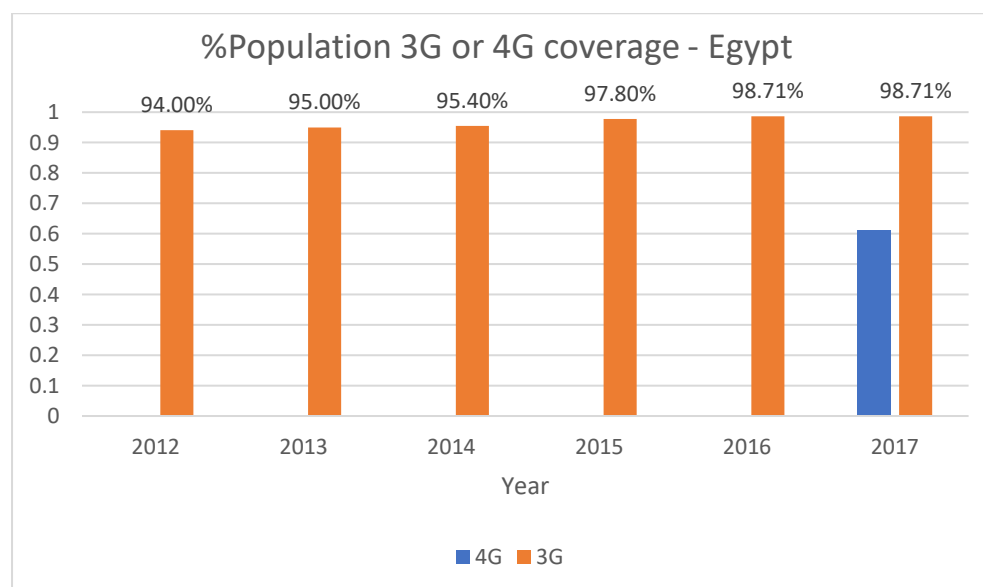


Figure 3 - source: ITU/ICT Indicators database – 2018

Whilst 94% might seem high for 3G and little different to 98.71% this is deceptive. In the UK, 50% of the population lives in around 2.5% of the landmass, and 90% in 15% landmass. In the UK going from 94% to 99% probably represents a very large increase in landmass covered and hence the number of base stations (and cost) – even though it does not sound that impressive.

In fact, in Egypt the landmass of the populated areas amounts to some 77,041 km² or 7.63% of landmass¹¹. The same reference seems to show that just over 41 million people live in around 28,400 km² i.e. 42.5% of the Egyptian population lives in 2.81% of the landmass.

This could be especially pronounced when one considers the average population density of Egypt is around 2.5 times less than the UK's (see tables 4 and 5¹²). The 61% population for 4G coverage shows just how far there is to go in Egypt in terms of investment in 4G base stations to get to figure approaching 3G. It should also be remembered that the cost of upgrading from 3G to 5G is much greater than from 4G to 5G (see cost model below).

¹¹ <http://www.citypopulation.de/Egypt-Cities.html>

¹² Tables 4 and 5 use different population dates and sources so have small differences.

The table below gives an indication of where the region is in terms of the investment cycle. One might expect that new investment in 5G might begin 10 years after the deployment of the previous technology.

4G % pops. coverage	2014	2015	2016	2017
Algeria	0%	0%	3.62%	30.49%
Iraq	0	0	0	0
Jordan	80%	80%	87%	90%
Kuwait		96.60%	98%	99.60%
Morocco	0	45.44%	68%	93%
Oman	76%	86%	88.77%	92.10%
Qatar	58%	95%	99.04%	99.50%
Saudi Arabia	82%	85%	88%	90%
Tunisia	0	0	73%	87%
UAE	85%	95.29%	99.60%	99.64%

Table 2 - Source ITU/ICT Indicators database 2018

Looking at *Table 2* suggests that the MENA region began investment in 4G around 2014 (with GCC slightly earlier), so we would not normally expect to begin 5G investment until 2024, with wide area coverage perhaps 2-3 years latter (depending on population density). This would suggest under normal investment cycles 5G would be wide area (i.e. 80 to 90% population coverage) by the year 2026 or 2027. Thus, without either some very strong benefit of 5G over 4G, and or some form of incentive/help, the goal of 5G being able to have a major impact on MENA economies by say next year, seems unlikely.

A more cautious approach to 5G – (build it and they will come?)

As was discussed above, the business cycle is not ideal for commercial deployment of 5G this year. The landscape for mobile has changed much since the internet dot-com bubble of 2000 when 3G was being deployed. Many operators then bid what were in retrospect overly high prices in 3G spectrum auctions. This has given many potential mobile investors a more sceptical approach, and made operators focus much more on ensuring there is a credible business case. In essence then, investors are much warier about mobile following the 3G experience, and in many parts of MENA are really just starting to deploy 4G (as a wide area technology).

Looking back, the technical advantages of 4G over 3G were much clearer - with much higher data rates and a better user experience. In many ways 3G was really not primarily designed for internet World-Wide-Web use of the world today. Many believed before 2000, that for 3G video conferencing would be the “killer application”.

It is easy to forget that the first iPhone was announced in 2007. 3G evolved to offer better data rates than GPRS in the 1990's but was not designed from the ground up for an iPhone and iPad world. Even in 2011 the average monthly UK mobile data use per connection was only 100 MB¹³.

¹³ https://www.ofcom.org.uk/data/assets/pdf_file/0028/98605/Pricing-report-2017.pdf - ref.1

The world was very different when 4G was being standardised in 2010¹⁴ with YouTube (purchased by Google in 2006) serving more than 2 billion videos a day according to Wikipedia.

4G was a major improvement on 3G in not only the data rates, but easier for operators to implement a single packet switched only network¹⁵ and cater for voice and video. That is with 4G, they did not need to deploy a separate circuit switched network for voice (as was needed for the first 3G networks).

The first 4G spectrum auctions taking place in Europe were with the German auction in 2010, France in 2011 and the UK in 2013. This timeline allowed 4G to be developed to cater for what was recognised then to be quasi exponential growth in data demand, not for video telephony, but the world of apps and *YouTube*. A far cry from the year 2000 when some quipped that the “killer app” for mobile was SMS. Whilst Netflix was around (founded in 1997) there was no suggestion (at least in this region) that 3G would cater for this video service.

Today, reports from OpenSignal show average download speeds of over 40 Mbps with LTE (in the top markets), with the OECD average monthly mobile usage of around 3 GB, with Finland on 15.5 GB per month. This is a level of demand that would be inconceivable in 2000. Hence 3G was not designed to operate in such an environment. 3G has evolved with HSPA (and was pushed by WiMAX), but was fundamentally a 20th century radio technology when the internet was not as ubiquitous as it is now.

So, the commercial push to upgrade from 3G to 4G was strong. It is less clear if such an incentive applies to upgrade from 4G to 5G in the near future and what extra revenue it would generate.

This does beg the question of what we mean by “*upgrade to 5G*”. Traditionally that has meant making it a wide area technology with over say 80% population availability. However, this may change with 5G. The question then becomes what impact is there on potential operator revenues if a more piecemeal approach is taken to 5G deployment? Will consumers pay extra for enhanced mobile broadband (eMBB) if less than 1% of the landmass is covered? Will mission critical services (such as police and ambulance) pay extra for 5G when in 99+% of locations they use 4G?

The 5G Commercial Strategy and service offering

In terms of deploying a wide area service offering to a large number of consumers it seems almost axiomatic that the mobile operators will need to make the required investment in 5G. It is possible that spectrum could be reserved for verticals and these industries (automotive, medical, industrial production etc) could deploy 5G in an ad-hoc manner. Perhaps 5G at a hospital, or at a factory, but not in a ubiquitous manner. Table 4 and Figure 5 however shows the extent of the investment already made by the mobile operators in terms of towers. If a tower cost around \$100k capex that gives an idea of the huge investment required to get wide area coverage.

It has been suggested that 5G could be deployed in a more piecemeal way. That is in high density areas first and relying on 4G as a fall back. However, the extent of the geographic coverage must have an impact on the price users will pay. If consumers cannot tell the difference between 5G and 4G service, then that begs the question of why deploy it. In any case further work is required to see what the impact is on revenue of hotspot/piecemeal deployment.

¹⁴ 3GPP Release 9.

¹⁵ 3G had a circuit switched part that was used for voice in many networks.

It is not clear why consumers would pay extra for a service that is not available very widely. It is also not clear why emergency services would pay beyond what they would for 4G in such circumstances. The Internet of Things (IOT) revenue stream is also not clear, and large segments of the IOT market might be served using 4G (or privately run 5G networks). The past experience of launching mobile technologies seems to show that consumers at least want a near ubiquitous service and will not pay more for a very geographically limited one.

This then presents the “chicken and egg” conundrum. If opcos don’t build it then they will not get the extra 5G revenues. But to get those revenues they need to commit to significant investment to say 80 to 90% of the population. A counter argument might be that consumers really only pay a flat fee for their mobile service and hence only investment by one opco drives the others (i.e. competition).

In the case of 5G this probably requires a larger investment as the higher frequencies used for 5G (3.5 GHz as compared to 1800 MHz used now in urban areas) could well suggest more sites (although vendors suggest this can be overcome). The main elements that are suggested as part of the 5G service offering are:

1. Higher user and peak data rates – with perhaps 10x higher (than LTE) user experience data rate;
2. Much higher connection densities for devices (such as IOT), increasing 100,000 per km² to one million per km²;
3. Ten- or 100- times better network energy efficiency;
4. Much lower latency than LTE (1 ms).
5. Three times as spectrally efficient.
6. Much lower Opex (than LTE).

This is typically thought of in terms potential markets in the figure below.

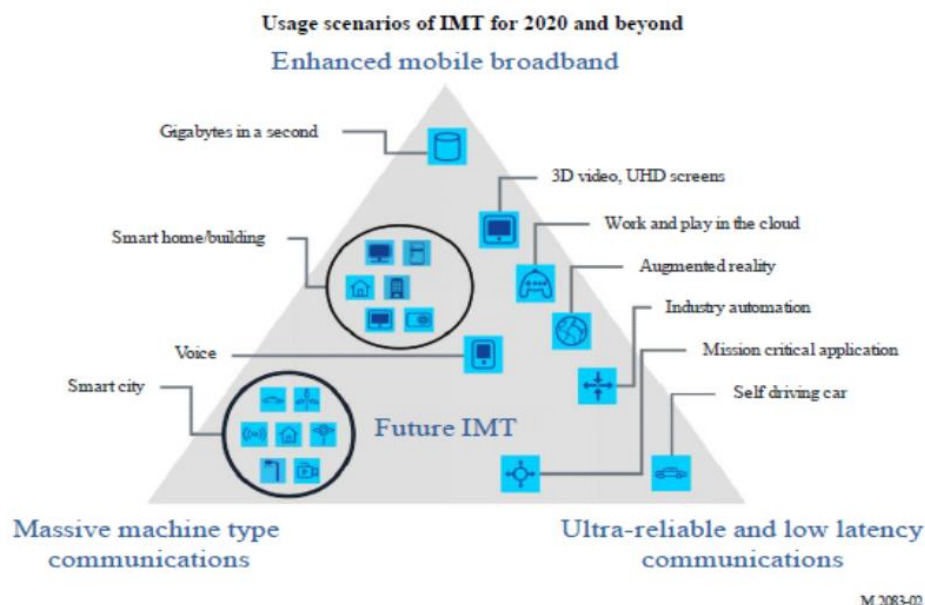


Figure 4 – source ITU

The complexity is understanding how much each market could generate and how much could be captured by a mobile operator. Some of the verticals suggested are areas that mobile opcos have

very little experience of, such as health and industry automation. Some of these markets can be served by private networks, for example a municipality setting up Wi-Fi like services in a city for smart city services. For industry automation we have already seen in Germany the suggestion of local licensing for private 5G networks that companies such as Audi and Siemens wish to use¹⁶. This further erodes potential revenue streams for mobile opcos.

Whilst not part of the service offering reduced opex is mentioned above. If one assumes opex dropping from say 10% to 5% pa, this is still quite a small value compared to capex. For example, if the capex was \$100 m, and the overall opex dropped from \$10 to \$5 million pa that would be a payback of 20 years. It should also be remembered that to 4G will probably continue to operate for many years so there will be no opex saving on those assets.

Cost Model

The cost model has been developed based on a high-level analysis of building a network from the bottom-up, using the number of sites within a country, and an analysis of what the costs might be to upgrade such a network to 5G. These costs are taken from a UK paper¹⁷. This requires that the assumptions be made about what upgrades are required and how much these upgrades will cost.

Figure one: Tower counts across MENA markets

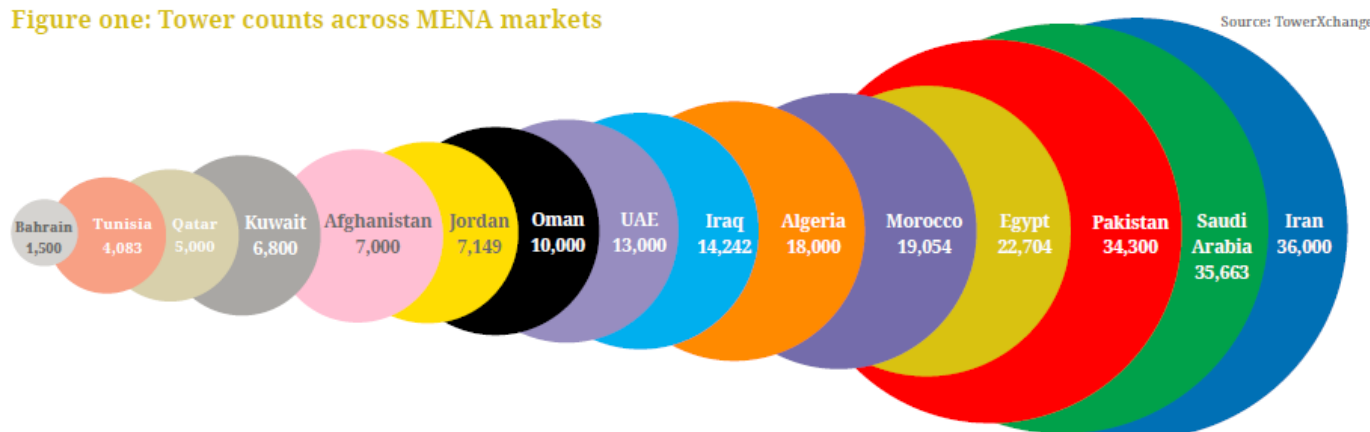


Figure 5 - Source: TowerXchange¹⁸

The main driver for costs is the number of base station sites (and it is assumed all will need to be upgraded to 5G for a full-wide area network), and the densification required for small cells (as well as backhaul and core network upgrades).

It seems likely that while the macro networks will continue to grow at a few percent per year (to naturally improve coverage) the major cost driver on densification will be the need to deploy very small cells in urban and suburban areas. These cells will be using higher frequency bands (C band 3.4-3.8 GHz) and will be smaller because of the higher frequency they use. The exact amount of densification is not clear, and vendors are suggesting that perhaps these new 5G cells will map onto

¹⁶ <http://gulfsouthtowers.com/german-industry-associations-urge-regulator-to-award-3-7ghz-spectrum/>

¹⁷ <https://www.itrc.org.uk/wp-content/PDFs/Exploring-costs-of-5G.pdf> - Table 7.

¹⁸ https://www.towerxchange.com/wp-content/uploads/2019/01/TX_MENAProspectus_2019.pdf

an operators' existing 1800 network for downlink and using another frequency band for uplink. However, this is not universally accepted, and some believe that a densification of small cells in high traffic demand areas (urban and suburban typically) will be required.

According to data from Elisa's 5G deployment in Finland the increase coupling loss (i.e. power reduction in the radio receiver) due to 5G deployment in the 3.5 GHz band (over LTE 1800) is on average 5-6 dB. This means that depending on the radiowave propagation law assumed (3.5 or 2) the densification required for 5G (C band sites) over LTE 1800 is a factor of two to four. For the purpose of this analysis a factor of two is assumed, although a case for four could be made based on what is the appropriate propagation model to assume in this case¹⁹.

It is assumed that as a rough rule of thumb 50% of an operator's sites are for rural/low density coverage. Hence 50% are for capacity and it is in these areas where densification will happen. For example, with Algeria there are 18,000 sites, so 9,000 will be for capacity and in these areas will require densification for 5G C band deployment. As discussed above this densification factor is assumed to be two, hence the total number of new small cells is 18,000. This issue of rural sites is discussed in more detail below.

Another element in the model is to make some allowance for the fact that the costs determined are for use in the UK. Some of the costs will vary in local markets, e.g. the cost of labour in Algeria will be less than the UK (all other things being equal). This allowance is done by assuming that some element of the costs may be local, for example building a macro site (25 metre tower). Other costs such as 5G radio equipment may not be, and in theory is fixed at an international price (although in practice the price a vendor charges for 5G base stations could well be commercially confidential).

A simple method is assumed that in the case of a macro base station 70% of the total cost is determined by the ratio of GDP to the UK (as the benchmark cost). This 70% is multiplied by that GDP ratio. This is then added to the 30% cost of the UK price – which is assumed to be fixed as it is equipment manufactured elsewhere (RF devices say) and imported. This tries to account for the fact that we see mobile services in countries with very different average revenues per user (ARPU). For example, in Algeria with an ARPU of \$4 per month, compared with Kuwait on \$25 per month. If this were not the case, then mobile services in low ARPU countries would not be deployed commercially.

The ARPU (i.e. *all revenue* divided by *all subscribers* – not just revenue from subscribers) is used to determine the total revenue. It is assumed that 5G will add 5% per annum as extra revenue. This is assumed from Ericsson²⁰ who suggest that based on the 10 industries they studied the maximum potential increased revenue for operators could be 36% over 6 years. This is assumed to translate into 5% CAGR, which seems reasonable given the adoption rates of new technologies is initially slow. It is assumed this 5% CAGR (Ericsson maximum) is for wide area deployment.

¹⁹ In the case of very short-range cells that are line of sight an inverse square law would be assumed, all other things being equal – which would make the required densification factor for these small cells a factor of four.

²⁰ <https://www.ericsson.com/assets/local/networks/documents/report-bnew-17001714.pdf>

The table below shows how these ARPU were used to generate a revenue figure.

pops (m)	country	arpu€ per month	\$ per month	ann. Rev \$m
40.61	Algeria	€ 4.00	\$4.56	\$2,222.18
1.425	Bahrain	€ 14.00	\$15.96	\$272.92
95.7	Egypt	€ 2.37	\$2.70	\$3,102.75
37.2	Iraq	€ 6.00	\$6.84	\$3,053.38
9.46	Jordan	€ 8.70	\$9.92	\$1,125.89
32.3	KSA	€ 16.00	\$18.24	\$7,069.82
4.05	Kuwait	€ 22.00	\$25.08	\$1,218.89
35.3	Morocco	€ 6.00	\$6.84	\$2,897.42
4.42	Oman	€ 21.00	\$23.94	\$1,269.78
2.57	Qatar	€ 27.00	\$30.78	\$949.26
11.4	Tunisia	€ 4.35	\$4.96	\$678.39
9.27	UAE	€ 21.00	\$23.94	\$2,663.09

Table 3

An important element of the costs will be the spectrum fee. Auctions are used on some occasions in the MENA region, however the majority of spectrum awards seem to be based on spectrum pricing. The level of this pricing varies from market to market by appears in many countries to be significant in value.

A recent award in Saudi Arabia for 2.3 and 2.6 GHz (Jan. 19) saw STC pay around \$100m for 100 MHz. This was used as a benchmark price for spectrum in the region but using modifiers for the differences in population and the relative GDPs. It is assumed that to deploy 5G will require around 500 MHz of spectrum. It is assumed that 400 MHz will come from the C band (3.4 to 3.8 GHz) and identified in Europe as the main 5G capacity band. A further 100 MHz would need to come from below perhaps 1 GHz to allow cost effective coverage. The UAE recently assigned spectrum for 5G from the C band. Using the funding formula in UAE²¹, and assuming the above spectrum distribution for 500 MHz would suggest an annual spectrum fee of around \$44 million per year. Over a 15-year spectrum licence this equates to \$660m. The cost model in this paper has assumed around half of this, but less than 500 MHz may be required in UAE for 5G.

The figure below gives the percentage of the total costs the spectrum fee represents. The benchmark is the Saudi Arabia auction of January 19. How valid this is depends on how the KSA award compares with others. The Saudi auction of June 17 saw a price of \$1140 m for 100 MHz of 1800 MHz spectrum (Zain and Mobily)²². The spectrum fee assumed in the cost model in this paper is ten times less than the spectrum fee from June 17.

One might argue that the 1800 MHz band has more value than 2.3 and 2.6 GHz bands, but not times 11.4. The C band would have less value, but one needs to add in the 100 MHz of coverage spectrum required below 1 GHz – which will have a relatively high value.

²¹ <https://www.tra.gov.ae/assets/97lySmeo.pdf.aspx>

²² <https://www.telegeography.com/products/commsupdate/articles/2017/06/08/stc-zain-mobily-awarded-additional-spectrum/>

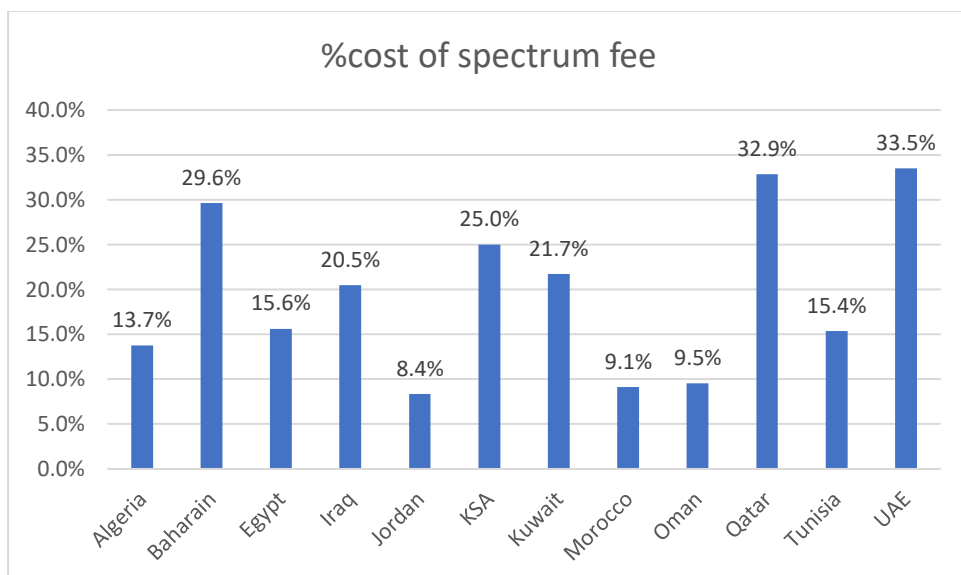


Figure 6

Based on the above assumptions the table below lists the steps used in the calculation.

step	description	Example - Algeria	comments
1	Determine sites numbers - towerxchange	18,000	Basis of bottom-up model
2	Cost of upgrade to all sites for 5G – Annex1 <u>UPGRADE COST</u>	18,000 x £15,000	To have a wide area network all sites need to be upgraded to 5G.
3	Determine densification of capacity areas for 5G C band and use Annex 1 to cost. – <u>DENSIFICATION COST</u>	18,000 x £15,800	In high demand areas C band small sites will be used for capacity.
4	Assume 10% increase in macro cells to improve overall coverage and capacity and cost using Annex 1.- <u>UK cost- NEW MACRO COST</u>	1,800 x £58,900	Over time high tower (macro sites) increase to improve coverage.
5	determine UK/country GDP ratio. X UK cost by 70% of cost to convert macro cell costs. Add 30% of UK cost as fixed. - <u>NEW MACRO COST LOCAL</u>	0.1 GDP ratio for Algeria (\$4,123/\$39,720)	As the costs are from the UK some account of local costs needs to be made.
6	5G will require back-haul upgrades to carry more data from sites to core network. Assume 25% of upgrade cost (step 2). Also assume local cost element and use GDP modifier. <u>UPGRADE BH COST</u>	18,000 x £15,000 x 0.1	5G will generate significantly more traffic than 4G was designed to cope with so the capacity from the base stations to the core network needs to be increased. It is likely that this will be based on local costs for laying fibre for example.
7	The small cells from step 3 “densification” will also need to be	18,000 x £15,800 x 25% x 0.1	Fibre to small 5G cells in urban areas is assumed a

	connected by fibre probably. Assume 25% as suggested by ITU report ²³ . Assume local cost modifier based on gdp ratio. <u>FIBRE SMALL SITES</u>		local service and hence as the base cost is a UK number the 25% figure is x by gdp ratio.
8	Sum of above costs gives the total cost excluding the required core network upgrade. <u>TOTAL-CN</u>	<u>UPGRADE COST + DENSIFICATION COST+ NEW MACRO COST LOCAL + UPGRADE BH COST + FIBRE SMALL SITES</u>	Total cost minus core network. According to ref. 1 this is 10%
9	Total cost = step 8 + 10% <u>TOTAL COST</u>	Above total x 1.1	Overall cost used to give a final figure.
10	ARPU per year x total population x 5% cagr. This is used in conjunction with the assumption that 5G will add 5% per annum growth in revenues. <u>REVENUE PA</u>	Gives annual revenue used with overall cost to work out payback period not including spectrum fees <u>PAYBACK</u>	ARPU is assumed as all revenues over all subscribers (i.e. including call termination etc but not terminal rental). Assume 100% penetration.
11	Spectrum Fee is calculated based on the assumption that 500 MHz is needed for 5G, and that the cost is \$100m per 100 MHz. This uses KSA as benchmark, so GDP relative to KSA used, as well as relative population sizes. <u>SPECTRUM FEE</u>	\$100m x 5 x (0.1/0.52) x (40.61/32.3) Used to calculate payback with spectrum fee <u>PAYBACK-SF</u>	Gives a value for spectrum licensing based on the outcome of the January 19 KSA award 2.3 and 2.6 GHz based on STC payment.

Assume \$1=£0.76

Table 4

Quality of Service and Coverage

As has been noted above the model is driven by site numbers, but this does not take into account what the quality and coverage of networks in one country might be when compared to others. For example, table 2 shows that 4G coverage varies widely from country to country and this would affect the cost of upgrading a network to 5G. If we consider Iraq, it has no 4G coverage so the above methodology should be adapted to add a factor on to Iraq because it will not be upgrading its 14,200 sites from 4G, at £15k but using a site with no 4G-LTE at a cost of £58,900 per site. This could add \$600m to Iraq's costs.

One could also look at the metrics of users per site, which would indicate capacity. More users per site meaning less capacity than a network with fewer users per site (all other things being equal). The other metric would be to do with coverage, and hence how many sites there are per unit area. This gives a high-level comparison (probably) about how much of the land area is covered. As

²³ https://www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-BB.5G_01-2018-PDF-E.pdf - figure 11.

discussed above relying on percentage of population can be misleading due to the way populations are distributed in countries.

The table below shows these metrics for various MENA countries.

pops (m)	country	towers	area km ²	towers per km ²	people per tower	pop density
1.425	Bahrain	1,500	758	1.979	950	1,880
4.05	Kuwait	6,800	17,818	0.382	596	227
2.57	Qatar	5,000	11,586	0.432	514	222
9.27	UAE	13,000	83,600	0.156	713	111
9.46	Jordan	7,149	89,342	0.080	1,323	106
95.7	Egypt	22,704	1,002,000	0.023	4,215	96
37.2	Iraq	14,242	435,244	0.033	2,612	85
35.3	Morocco	19,054	446,550	0.043	1,853	79
11.4	Tunisia	4,083	163,610	0.025	2,792	70
40.61	Algeria	18,000	2,381,741	0.008	2,256	17
32.3	KSA	35,663	2,149,690	0.017	906	15
4.42	Oman	10,000	309,500	0.032	442	14

Table 5

What might reduce costs and payback periods

The major driver of costs is the number of towers/sites required. Anything that can be done to reduce this will save on costs. This also raises the issue of the number of operators a country licences, and to what extent the revenue and costs match to support that number. In Ofcom's recent proposals for auctioning 5G spectrum²⁴ they noted that whilst competition is an important driver of investment there are limits to the extent it can drive mobile coverage expansion. Ofcom has estimated that this commercial investment in coverage driven by competition sits at around 82% to 84% of the UK landmass (Section 4.21). To move beyond this requires some form of "intervention". It may well be that a wide area network 5G coverage (as is being developed for 4G in many markets) cannot happen without some form of intervention.

The main cost savers would seem to be sharing a common rural network, at least for a period of time. As a rough rule of thumb this would mean that might mean saving upgrading 50% of sites. This issue of rural sharing is explored below. If such sharing were also allowed in urban/suburban areas that could further reduce costs. The ultimate level would depend on the number of main commercial operators in a market.

²⁴ https://www.ofcom.org.uk/data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf

Rural Sharing

The cost savings from rural sharing will depend on the number of sites that are rural, or put another way not required for capacity. This will be driven by the population distribution of a country and needs a detailed mapping exercise to determine. It should however be possible to get some feel for this based on the population density of a country, and this is shown below.

Country	Area (km ²)	Population	Density (/km ²)	relative to UK pops density	number main opcos	sites
		-2016		263		
Algeria	2,381,741	40,606,052	16	6.08%		18,000
Bahrain	758	1,425,171	1,646	625.86%	3	1,500
Egypt	1,002,000	95,688,681	100	38.02%	3	22,704
Iraq	435,244	37,202,572	70	26.62%	3	14,242
Jordan	89,342	9,455,802	71	27.00%	3	7,149
Kuwait	17,818	4,052,584	200	76.05%	2	6,800
Morocco	446,550	35,276,786	80	30.42%	2	19,054
Oman	309,500	4,424,762	9.2	3.50%	2	10,000
Qatar	11,586	2,569,804	154	58.56%	2	5,000
Saudi Arabia	2,149,690	32,275,687	13	4.94%	3	35,663
Tunisia	163,610	11,403,248	65	24.71%	3	4,083
UAE	83,600	9,269,612	99	37.64%	2	13,000

Table 6 - Sources: Wikipedia +Towerxchange

The population relative to the UK has been chosen because the author feels that in the UK it could be assumed that 50% of sites are rural and 50% are in capacity driven areas. According to data from Ofcom around 85% of land mass is covered in the UK. This data is not known for MENA markets.

The lower the population density the higher the number of rural sites there are likely to be (all other things being equal). Also, the greater the number of commercial operators the greater the potential saving. The lowest population density is Oman with 9.2 people per km² on average with 2 operators. In Bahrain however the population density is very high at nearly 1,700 per km² (based on 2016 figures) – which suggests there are not many sites that can be classified as rural.

In theory to estimate the rural costs saving for Egypt say, one would make an assumption such as 50% of the sites are rural. This would suggest there are around 11,000 rural macro sites, or 3700 per opco (with 3 opcos). A single common 5G rural network would save 2/3 'ds of the 11k sites, or around 7,300 sites. This could then be factored into the cost model and a new payback period calculated. However, it may be that the current level of geographic coverage may wish to be improved, and hence the number of rural sites would increase. This would make the potential costs savings more.

In the absence of more detailed data all it is possible to say is that rural coverage is likely to be a major cost for 5G. Some form of cost sharing by having a single network in rural areas is likely to offer a significant saving in markets.

Cross-border coordination issues for radio interference

Radio services that might cause harmful interference need to be coordinated with neighbouring countries to ensure that this is controlled. The international framework for this is set at an international level by the ITU-R²⁵. Mobile radio systems such as 3G and 4G have had to follow agreed coordination procedures since they were initially deployed. In general, these procedures have tended to be based on bi or multi-lateral arrangements. This has been based on the mobile services having the same status in the international radio regulations as other radio services.

Unfortunately, 200 MHz of the C band (3.6 to 3.8 GHz specifically) has no protection under the ITU rules, and therefore cannot be registered. This creates uncertainty and could add to deployment costs in border regions. The exact scope will depend on what percentage of the population might be affected. For more detail see articles by the author on this for KSA²⁶ citing the example of the Finnish auction²⁷. The KSA presentation shows that 20% of the Saudi population might be affected by this issue in the 3.6 to 3.8 GHz band.

Conclusion

There is a great deal of uncertainty about the business case for 5G. These relate to the revenues that 5G will offer in addition to 4G. The costs associated with 5G wide area deployment are high. It may be that high spectrum fees could have a big impact on the business viability. If the aim of 5G is to provide a wide area service, as has been the case with 3G and 4G, then there should be some consideration given to having perhaps a shared network in rural areas, at least for a period.

Without some sort of assistance 5G may well be limited to very few areas such as dense urban (i.e. hotspot), and so will be of much more limited benefit for consumers and the economy.

The analysis presented here can help serve as a basis for further discussions with local stakeholders. Local conditions such as the percentage of sites without 4G could drive up the costs and hence increase payback periods in this paper.

²⁵ <https://www.itu.int/en/ITU-R/Pages/default.aspx>

²⁶ <https://www.slideshare.net/RobertoErcole/samena-riyadh-workshop-december-18>

²⁷ <https://www.linkedin.com/pulse/finnish-5g-spectrum-auction-lessons-roberto-ercole/>

Annex 1 - Costings

Strategy	LTE availability	Cost type	Capex (GBP)	Capex time trend	Opex (GBP)	Opex time trend	Source
Integrating spectrum into the macrocelluar network	Site with 4G LTE	Additional carrier on current BS	15,000	-3%	1,800	0	MTC 2015
	Site with no 4G LTE	Deploying a multicarrier BS	40,900	-3%	3,898	-5%	MTC 2015
		Site lease	-	0	5,000	3%	MTC 2015
		Civil works	18,000	0	-	3%	5G NORMA (2016)
		Fibre backhaul Urban: 1 km	20,000 per km	0	-	0	Provisional assumption
		Fibre backhaul Suburban 1: 2km, Suburban 2: 4km	20,000 per km	0	-	0	Provisional assumption
		Fibre backhaul Rural 1: 8km Rural 2: 10km, Rural 3: 20km, Rural 4: 30km	20,000 per km	0	-	0	Provisional assumption
Network densification through small cells		Small cell equipment	2500	-3%	350	-5%	5G NORMA (2016)
		Small cell civil works	13300	0	0	0	5G NORMA (2016)
		Small cell site rental	-	0	5,000	0	Provisional assumption
		Small cell backhaul	-	0	1,000	3%	5G NORMA (2016)
Core upgrade cost on all strategies			10% mark-up on RAN deployment cost	0	-	0	Provisional assumption

Source: Oughton and Frias for National Infrastructure Commission (UK) "Rollout Implications of 5G in Britain" - 2016²⁸