Response to Public Inquiry

Detailed response (Non-confidential version)

"Allocation of spectrum bands for mobile broadband service in Malaysia"

30th August 2019

Confidential information as redacted is because the information is proprietary, confidential, commercially sensitive or contains Celcom's forward-looking statements.

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Content

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Exhibits

1 700MHz award mechanism and timeline

MCMC would like to seek views on the proposed allocation plan for the 700MHz band and in particular: i) Award mechanism; and ii) Timeline for assignment.

1.1 The 700MHz award mechanism

1.1.1 MCMC's position

MCMC recognises that there is a trade-off between extracting money from mobile operators by means of a spectrum auction and using the 700MHz spectrum to achieve the goals of the NFCP, in particular that of providing wide geographic coverage. Therefore, MCMC is considering allocating the 700MHz band by way of a Spectrum Assignment ("SA") through a comparative tender ("beauty contest") process.

1.1.2 Celcom's position

Celcom agrees with MCMC's rationale and the conclusion. Celcom is in favour of a spectrum assignment by comparative tender ("beauty contest") where the scoring focuses on 700MHz coverage roll-out in rural Malaysia, in support of NFCP objectives, and the credibility to deliver the promised roll-out. The credibility to deliver the promised coverage roll-out should mainly be scored based on historical track record e.g. network rollout, efficiency, capacity to serve, and financial strength e.g. ability to raise funds for network rollout & maintenance and spectrum fees.

In order to ensure that a coverage roll-out commitment is delivered, there must be substantial penalties backed by performance bonds.

Exhibit 1: Proposed scoring for 700MHz assignment

Criteria	Weightage
Track record e.g. network rollout, efficiency, capacity to serve	40%
Financial strength e.g. ability to raise funds for network rollout & maintenance and spectrum fees	30%
Roll-out plan	20%
Commitment to network sharing	10%
Total	100%

1.1.3 Discussion and evidence

A comparative tender allows MCMC to score tenders for the 700MHz spectrum consistent with the goals of the NFCP, notably to bring coverage to 98% of populated areas with an average speed of 30 Mbps by 2023.

MCMC is right in stating that most countries assigned 700MHz by means of an auction. This assignment mechanism is consistent with their countries' policy objectives and particular legal environment. If MCMC were to imitate other countries and auction the 700MHz spectrum it would in effect import other country's policy objectives instead of pursuing Malaysia's policy objectives with regards to developing Malaysia's mobile broadband infrastructure. Therefore, it is not helpful to look at how spectrum was assigned in other countries unless these countries had development objectives that are similar to Malaysia.

Chile provides an example where the policy objectives are similar to those in Malaysia. The government has a broadband development objective. The prices for 700MHz were set low at 0.017 US$ per MHz per head of population. However, there was a substantial deployment obligation. While nominally the assignment was an auction, in effect it amounted to assigning the spectrum to those operators who were prepared to meet the coverage obligation.

Some countries have a legal obligation to use a market-based mechanism to assign spectrum. An auction where operators bid money to acquire spectrum is a market-based mechanism. An auction where operators bid coverage is also a market-based mechanism and can be equally transparent. However, the question arises what happens if an operator obtains spectrum and subsequently does not fulfil the coverage obligation.

The most efficient assignment method would be a comparative tender ("beauty contest") that is evaluated based on criteria as described in Exhibit 1. Therefore, the credibility of the bidder and the realism of the bid must be a key criterium in scoring bids in a comparative tender.

1.2 Timeline for the 700MHz assignment

1.2.1 MCMC's position

MCMC states that timely release of the 700MHz band is an important component towards achieving the relevant NFCP targets.

MCMC proposes that the assignment process for the 700MHz band commences in the 4th Quarter of 2019 and targeted to be completed by the 2nd Quarter of 2020 with the band available to be used for mobile broadband service at the earliest in the 3rd Quarter of 2020.

1.2.2 Celcom's position

Celcom agrees with MCMC that the timely release of the 700MHz band is an important component towards achieving the relevant NFCP targets.

The timeline is governed by the timing of the ASO which, MCMC states, should be completed by the 3rd Quarter of 2020. Celcom seeks MCMC's support to ensure that this date is adhered to.

As regards to the timing of the assignment, we note that timelines tend to slip. We would therefore propose for MCMC to issue provisional assignment for the 700MHz by the end of 1st quarter 2020. This would allow operators who have obtained 700MHz spectrum to start building the network ahead of the availability date of the 3rd Quarter of 2020.

If the 700MHz assignment process completes at the end of Q1 2020 and the ASO completes at the end of Q3 2020, there will be a six months period during which the spectrum is not usable by mobile operators. Therefore, we would like to propose the SA payment (Price Component) to be made one month before the SA effective date.

1.2.3 Discussion and evidence

The 700MHz band (3GPP Band 28) has been in operation in Australia since 2014 and since then many other countries have licenced this band and operators have deployed the band for 4G (LTE). In Europe, operators will use this band as the 5G coverage layer from the end of 2019 / beginning of 2020 onwards.

The socio-economic benefit of better mobile broadband is clear as explained in chapter 7.4.1 below. Every year the 700MHz is delayed translates into a non-recoverable economic loss to Malaysia. Ensuring that the ASO is completed by Q3 2020 at the very latest is essential so that Malaysia is no longer deprived of the socio-economic benefit from mobile broadband services in the 700MHz band.

Issuing the provisional assignment at the end of Q1 2020 would give operators who were assigned 700MHz spectrum six months to order network equipment and start to deploy it. This means 700MHz mobile broadband could be available the day after the ASO is completed. The majority of LTE smartphones in use in Malaysia have the ability to use 700MHz (Band 28). This means the Malaysian population could immediately benefit from the 700MHz spectrum rather than waiting a further 6 months for operators to build the network.

2 700MHz optimum block allocation per operator

MCMC would like to seek views on the optimum spectrum block per operator for assignment of the 700MHz band.

2.1 MCMC's position

MCMC proposes to assign the 700MHz spectrum in four blocks of 2x10 MHz in the range 703-743 MHz paired with 758-798 MHz.

The 700MHz band (Band 28 in 4G and n28 in 5G) covers the range 703-748 MHz paired with 758-803 MHz. MCMC proses not to assign 743-748 MHz paired with 798-893 MHz, i.e. one 2x5MHz block would remain unassigned.

MCMC considers an assignment of less than 2x10 MHz spectrum is not ideal to deliver high data rates and assigning less than 2x10MHz may affect the ability of operators to achieve the NFCP targets and ensure improvements in QoS.

2.2 Celcom's position

2.2.1 Assigning the whole 2x45 MHz of the 700MHz band

MCMC rightly recognises the importance of 700MHz in the context of delivering the NFCP. The more spectrum that is assigned the better, because it increases the overall capacity, i.e. mobile broadband speed, in this band. MCMC also rightly notes that deploying 700MHz in less than 2x10MHz is inefficient. Nevertheless, MCMC proposes to hold back 2x5MHz from the assignment.

Withholding one block of 2x5MHz from the assignment is sub-optimal for the following reasons:

- For any operator or other entity to deploy a 700MHz LTE network in only 2x5MHz is highly inefficient. The cost per MHz deployed is almost twice as high compared to deploying in 2x10MHz.
- Initially the band would be used for 4G because it is of immediate benefit for most LTE smartphone users in Malaysia. However, globally 5G is already a reality and in Malaysia 5G is expected to be deployed from 2021. To provide a 4G and 5G coverage layer, operators require more than 2x5MHz of 700MHz spectrum. This is discussed in more detail under heading 2.3.2 below. In other words, a 2x5MHz block assignment does not offer a migration path to 5G.
- In the 5G specifications for a channel bandwidth of 5MHz the Sub Carrier Spacing (SCS) is limited to 15 kHz. With 10MHz or more the SCS is 30 KHz. 15 kHz SCS will not have as good latency as 30kHz SCS. Low latency is a key requirement for 5G and cannot be delivered in a single 2x5MHz block of 700MHz spectrum.

Celcom recommends assigning the entire 2x45MHz of the 700MHz band to those Malaysian mobile operators who have the ability to deploy the spectrum rapidly and widely. This would maximise the bandwidth available to mobile users, especially those in rural areas. Further it would maximise the economic efficiency because more spectrum would be deployed with a given amount of investment (see also Exhibit 4 below).

2.2.2 Preference for a wide band assignment

Celcom suggests assigning the 700MHz in three blocks of 2x15MHz each. This results in higher download speeds and generates cost efficiency compared to a 2x10MHz block assignment. This would allow MCMC to assign the spectrum to three operators, i.e. a sufficient number to maintain a competitive market. Of course it does not mean that only three players would have access to the 700MHz spectrum. Existing wholesale and national roaming arrangements would continue. All mobile operators would benefit from lower costs which translates into lower prices for the customers of all networks.

A second best option would be to assign the 700MHz band in three blocks of 2x10MHz and one block of 2x15MHz. This would be less efficient from a download speed and cost perspective but would still allow one operator to deploy efficiently in 2x15MHz and offer wholesale access to operators who did not acquire any 700MHz spectrum.

Celcom does not recommend a 2x20MHz block assignment. A block assignment of 2x20MHz would be even more cost efficient. However, if the spectrum is assigned to two operators with a 2x20MHz block each, there would be insufficient competition in the market. If the spectrum is assigned as one block of 2x20MHz and two blocks of 2x10MHz, the operator with 2x20MHz would have a 100% advantage over the other two operators. This would result in a competitive imbalance.

2.3 Discussion and evidence

2.3.1 Introduction

The 700MHz band is Malaysia's most important spectrum resource to provide mobile broadband coverage in the form of 4G and 5G. Once the spectrum is assigned, Malaysian operators will install the latest generation of radios. These radios are software defined and can operate as 4G as well as 5G. 3GPP Release 15 includes Dynamic Spectrum Sharing (DSS) which is a feature allowing operators to run 4G and 5G simultaneously in the same band and the same radio. Therefore, the 700MHz is not only key for 4G rural mobile broadband connectivity but will also provide the 5G coverage layer in urban and rural Malaysia.

In assessing the optimum block size for the 700MHz band, we need to take account of several factors as shown in Exhibit 2. Spectrum is a scarce resource which belongs to the Malaysian nation and MCMC should select the block assignment which produces the greatest consumer welfare.

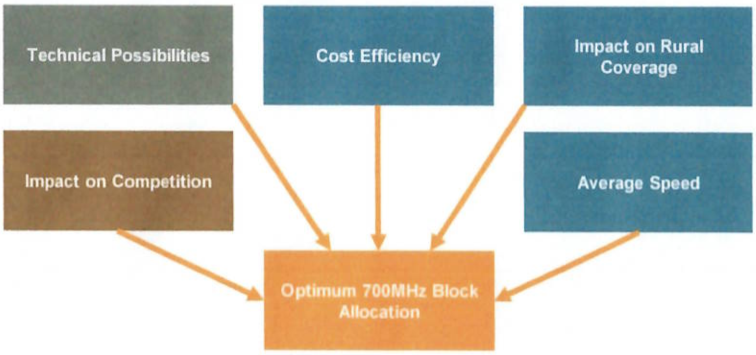
The key question is whether allocating the 700MHz spectrum in four blocks, as proposed by MCMC, produces a better outcome or whether allocating the spectrum in three blocks as proposed by Celcom produces greater benefits.

The answer to the optimum block allocation is framed by the technical possibilities and is a trade-off between opposing factors:

- A wider band assignment maximises cost efficiency and achieves the best data rates. This is very relevant for 4G but even more relevant for 5G.
- However, assigning the spectrum to 2 rather than 3 operators may have a negative impact on competition.

In the following, we provide evidence that the benefit of allocating the 700MHz spectrum in 3 blocks rather that 4 blocks produces greater consumer welfare. The evidence shows that a wider band allocation per operator is more efficient in delivering the NFCP objectives, results in lower retail prices and will not result in a lessening of competition.

Exhibit 2: Factors to asses optimum block allocation



Source: Coleago, Celcom analysis

2.3.2 Technical possibilities

A 3GPP specification for the 700MHz band exists for 4G (LTE) (Band 28) and 5G (Band n28).

- 3GPP defines the available channel width for 700MHz 3GPP Band 28 as 3, 5, 10, 15 and 20MHz radio channel bandwidth.
- For 5G band n28 has the channel bandwidth 5, 10, 15 and 20MHz.

The maximum channel width in a single radio is 20MHz. If an operator holds 2x20MHz or less, one radio is required. If an operator holds, say, 2x25MHz or more this operator would require two radios thus doubling the cost of the radio. Therefore, an allocation of more than 2x20MHz does not produce significant cost efficiency gains.

The other technical issue that must be considered is how an operator migrates the band from 4G to 5G. This is important because a 5G coverage layer is required from 2021, the likely date for 5G service launch in Malaysia.

In the introduction of the PI document, MCMC states: *The emergence of next generation mobile technology such as 5G technology enables gigabit speeds and offers low latency with high reliability for multiple types of use cases. In order to support these use cases, different spectrum bands are required.*

MCMC is right in making this important point. 5G requires spectrum for capacity, for example the C-Band (3.3-3.8GHz) as well as for coverage, i.e. the 700MHz band. The 700MHz band is the prime candidate coverage band for 5G (see Exhibit 3). In order to introduce 5G alongside 4G in the 700MHz band, operators require more than 2x5MHz. It would <u>not</u> be possible for an operator who holds only 2x5MHz to migrate smoothly from 4G to 5G. An operator with only 2x5MHz would have to wait to introduce 5G until 100% of their customers have 5G capable smartphones which would take 7 to 8 years. In contrast an operator with 2x10MHz of 700MHz could run 4G and 5G simultaneously in the same band i.e. there would be a 5G coverage layer from 2021.

Exhibit 3: Spectrum and relevance for 5G

	Coverage width	User through-put	Latency	Mobility	System capacity
Sub-1 GHz	****	*	*	****	*
1.5 – 2.6 GHz	***	**	**	***	**
3.3 – 5.0 GHz	**	***	***	*	***
24 – 40 GHz	*	****	****	*	****

Source: Ericsson, Coleago

2.3.3 Cost efficiency

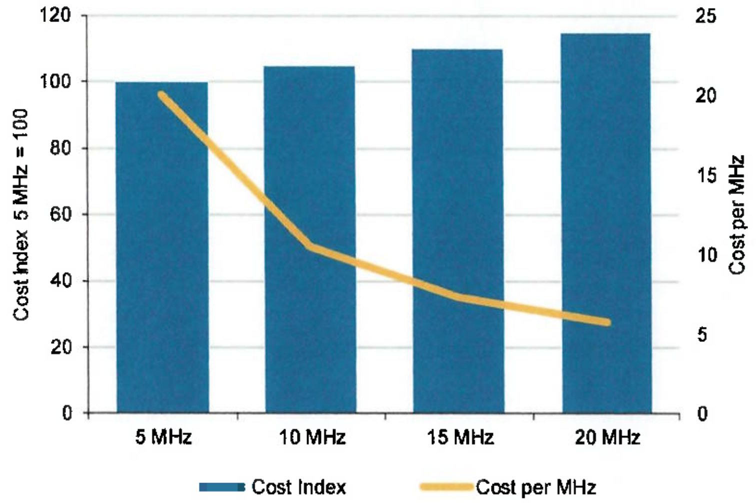
As regards capital expenditure (capex), the cost of installing 700MHz radios and antennae is roughly the same regardless of whether an operator deploys the band in 2x5MHz, 2x10MHz, 2x15MHz of 2x20MHz because in each case only one radio and one antenna are required. Vendors tend to charge a slightly higher software licence fee for more bandwidth, but the software licence fee increment is small.

The same is true for operational expenditure (opex). Site rental and maintenance costs which are the most significant opex items do not vary with bandwidth. A wide bandwidth deployment requires somewhat more power, thus creating a marginally higher opex for a wider band deployment.

The total cost of ownership (TCO) for every additional 2x5MHz deployed is around 5% more compared to the first 2x5MHz. This is illustrated in Exhibit 4 below. Moving from 5MHz to 10MHz produces 48% efficiency in the TCO per MHz and moving from 10 to 15MHz still produces an excellent efficiency improvement of 30%. Moving from 15 to 20MHz only produces a 20% efficiency gain. Moving from 20 to 25MHz would be inefficient because, as explained under "Technical possibilities" a second radio is required.

At first glance the benefit of lower cost is a producer benefit. However, mobile service provision in Malaysia is a highly competitive market. This means cost savings will be passed on to consumers in the form of lower prices by Gbyte of data. Prices fall to the point where operators earn their cost of capital. This means that consumers are the ultimate beneficiaries of a wide band allocation. The wider the band, the lower the cost, and the lower are retail prices.

Exhibit 4: 700MHz cost efficiency depending on width of band allocation



Source: Coleago

The horizontal axis indicates the channel width in MHz. For example, a 2x5MHz allocation has a downlink channel width of 5MHz and also an uplink channel width of 5MHz.

2.3.4 Download speed

The wider the band the higher the peak data rates. The peak data rate increases in proportion to bandwidth. There is also a small trunking efficiency associated with a wider channel. This leads to the conclusion that a wider band assignment of, say, 2x15MHz instead of 2x10MHz produces a better user experience. A three block assignment delivers 50% higher peak, average and cell edge speed.

The 3GPP specifications[1] detail the performance requirements for LTE advanced in terms of Peak spectral efficiency, cell average spectral efficiency and cell edge spectral efficiency. The system performance in terms of spectral efficiency for an LTE advanced deployment using 4x4 mimo in the downlink is as follows:

- Peak spectral efficiency 15 bps/Hz/cell
- Cell average spectral efficiency 3.7 bps/Hz/cell
- Cell edge spectral efficiency 0.12 bps/Hz/user

Based on the above, the table below illustrates the peak, average and cell edge throughputs that could be expected with 5, 10, 15 and 20 MHz downlink spectrum allocations. In rural areas users tend to be distributed over a wider area. Therefore the 50% better cell edge performance with a three block assignment is of particular importance in rural areas.

[1] 3GPP TR 36.913 specification

Exhibit 5: LTE Advanced downlink cell throughputs with mimo 4x4

Downlink MHz	Cell Peak (Mbps)	Cell Average (Mbps)	Cell Edge (Mbps)
5	75	18.5	0.6
10	150	37	1.2
15	225	55.5	1.8
20	300	74	2.4

Source: 3GPP TR 36.913

2.3.5 Impact on competition

Competition in mobile services network operation is important. Competitive markets deliver good outcomes for consumers because a) network operators compete to deliver the best network in terms of speed, availability, coverage and innovative services and b) retail prices are driven down to the point where producers only earn their cost of capital.

A measure of competition is the number of players with a comparable service offering in a market and their market shares. All things being equal, more players in a market mean more competition. Access to 700MHz spectrum is an important element for operators to have a comparable service offering and stay competitive.

Empirical evidence suggests that market structures with fewer mobile network operators may deliver better outcomes in terms of investment and network performance without adverse impact on retail prices:

- According to the GSMA, consumers in two- or three-player markets in Central and South America experience 4G download speeds that are up to 8 Mbps faster and this is due to the more concentrated market structure[2].
- Cross-country analysis suggests that average prices in 4-player markets are not lower than in 3-player markets[3].
- Average mobile capex per customer is marginally *higher* in 3-player markets than in 4-player markets, and this is true in both advanced and low GDP/capita economies[4]. This shows that the level of investment does not decline if a market becomes more concentrated.
- Total industry operational expenditure is lower in a 3-player market compared to a with more competitors. This means while capex per customer may be higher network opex per customer is lower so that the total cost of ownership per customer is lower.

In summary, network investment in a 3-player market will deliver significantly greater benefits for consumers than equal investment in a 4-player market. This is because there will be less duplication of investments in the 3-player market, and competition will ensure that part of the gains in productive efficiency are passed onto consumers in the form of lower prices.

2 GSMA report 'Assessing the impact of market structure on innovation and quality –Driving mobile broadband in Central America', May 2018 (available at: https://www.gsma.com/publicpolicy/driving-mobile-broadband-in-central-america).

3 Frontier Economics, 'Assessing the case for in-country mobile consolidation in emerging markets', a report for the GSMA, February 2015 (available at: https://www.gsma.com/publicpolicy/wp-content/uploads/2015/02/Assessing-the-case-for-in-country-mobile-consolidation-in-emerging-markets-report.pdf).

4 Frontier Economics, February 2015 (*ibid*). Also see Frontier's report for the GSMA 'Assessing the case for in-country mobile consolidation', May 2015 (available at https://www.gsma.com/publicpolicy/wp-content/uploads/2015/05/Assessing_the_case_for_in-country_mobile_consolidation.pdf).

There are also numerous international precedents in favour of consolidation and market structures with up to 3 mobile networks:

- We have seen recent consolidation from 4 operators to 3 in Australia, Austria, Germany, Ireland and the Netherlands[5].
- Other advanced economies with 3 mobile network operators include Belgium, Czech Republic, Finland, Greece, Japan, New Zealand, Norway, Portugal, South Korea and Switzerland.
- In the US, the proposed merger between T-Mobile and Sprint would lead to a market structure with 3 main national operators.
- In China, the government is mulling a merger between 2 of the 3 national operators (China Unicom and China Telecom), to accelerate the development and deployment of 5G technology[6] –this would effectively result in a two-player market.

Accordingly, assigning the 700MHz spectrum to 3 operators instead of 4 in Malaysia would be firmly in step with international trends, and would likely yield significant consumer benefits.

So far, we have only considered mobile network operators. However, the competition in mobile services also comes from MVNOs and smaller niche operators whose customer roam onto other networks. What matters to a user is a comparable service experience. An MVNO customer or a customer of a smaller operator roaming on the network of a larger operator with wider coverage experiences exactly the same service as a customer of the larger operator. That is to say service is comparable. Therefore what matters for smaller players is to have access to spectrum rather than owning spectrum.

2.3.6 Socio-economic impact of assigning 700MHz to three operators

The economics of serving mobile broadband users in urban areas of Malaysia are good. There is a high user density and urban consumers have high incomes compared to rural consumers. The concentration of businesses is also considerably higher in urban areas than in rural areas. Urban markets can support more than three operators. However, given the relatively small population of 32.5 million spread over a large area, the economics for mobile operators outside urban Malaysia are not ideal.

The mobile industry in Malaysia is now at the juncture of two major changes which necessitate very large investments, i.e. network capital expenditure (capex):

- 5G is a reality in some countries and Malaysia will follow soon. 5G enables the Internet of Things (IoT) with Massive Machine Type Communications (mMTC) and Ultra Reliable and Low Latency Communications (uRLLC). With this capability 5G is an enabling platform for what has been described as the "4th industrial revolution"[7]. Recognising its immense transformational value, governments in developed and developing markets are keen to facilitate the deployment of 5G mobile services in their respective countries. To ensure that Malaysia does not fall behind, operators in Malaysia need to make very large investment in 5G over the next three years.
- Malaysian policy objectives focus on the ICT development of the whole nation, including less populated parts of Malaysia. To deliver the goals of NFCP, notably to bring coverage to 98% of populated areas with an average speed of 30 Mbps by

5 The entry of Free Mobile in France in 2009 is one of few first-world examples of a three-player market moving to 4 mobile network operators. Singapore is another: after years of policies seeking to facilitate new entry, including spectrum reservations, a 4th licence was finally awarded to TPG in 2016 (see https://asia.nikkei.com/Business/Singapore-awards-mobile-license-to-Australia-s-TPG).

6 Source: Reuters, 4 September 2018 (see https://www.reuters.com/article/us-china-telecoms-merger/china-explores-merger-of-carriers-china-unicom-china-telecom-bloomberg-idUSKCN1LK0VQ).

7 Klaus Schwab, The Fourth Industrial Revolution, Magazine of Foreign Affairs, 12 Dec 2015

2023, substantial network investment is required. However, this investment will generate insufficient revenue and have negative impact on the return on invested capital (ROIC) of mobile operators.

In its present form with four main mobile operators and several other smaller wireless players, the mobile industry in Malaysia is barely sustainable. Given the challenges highlighted above, the mobile industry in Malaysia is likely to be negatively affected if the 700MHz is distributed between four operators. Ensuring that only three network operators deploy the 700MHz spectrum would significantly improve cost efficiency and industry economics. This would have the following benefits:

- At a given level of capital expenditure, operators can deliver more coverage and better quality of service in terms of speed.
- Given that Malaysia is a competitive market where operators earn no more that their cost of capital, a reduction in operator's costs will lead to lower retail prices in form a lower price per Gbyte of data.

Increased investment and lower prices would improve consumer welfare and drive wider adoption and use of mobile broadband services. The latter would promote digital inclusion and will enhance economic productivity.

2.3.7 Impact on rural coverage

There are three aspects to be considered to assess the 700MHz block allocation in terms of the impact on rural coverage:

- Minimising the negative return on investment in building rural coverage;
- Ensuring that people with non-VoLTE handsets can make voice calls; and
- Ensuring 700MHz is deployed quickly on a large number of rural cell sites, including new cell sites.

Minimising the negative return on investment in rural coverage

Achieving mobile broadband coverage in thinly populated rural areas is a key policy objective. Given this policy objective, the ability to cover rural areas in a cost effective manner is the most valuable attribute of 700MHz spectrum.

The reason why rural areas are not covered well or at all is of course that each cell tower covers only a few customers and those customers have on average lower incomes than customers in cities. The revenue potential within the coverage area of a rural cell site is small and yet operating costs tend to be high because it is expensive to build and operate a cell site in a remote area and backhaul the traffic. Therefore the return on investment in building coverage in sparsely populated areas is low or negative.

If this limited revenue potential has to be shared between multiple operators the economics are further reduced. Certainly it does not make sense for four operators to build rural 700MHz coverage in the same area. If the business available in rural areas is divided between 3 rather than 4 operators this results in a better business case, albeit still negative, to build rural mobile broadband coverage.

Even if there are only three operators competing for mobile broadband customers in rural areas, there will still be many areas where there is no commercial case to build coverage and the return on investment in urban areas has to subsidise the rural areas which are loss making. This is another strong reason for maximising the cost efficiency of the 700MHz block allocation i.e. allocate the spectrum in three rather than four blocks.

Serving rural users with non-VoLTE handsets

3GPP technical specifications for the 700MHz spectrum only exists for 4G (LTE) and 5G. The spectrum cannot be used to provide GSM or 3G (HSPA) connectivity. This means that only users with VoLTE enabled 4G handsets can make full use of the spectrum.

- Users with GSM and 3G handsets could not use the spectrum at all. This is an issue because in rural areas the incidence of simple 2G or 3G phones is higher than in urban areas because rural incomes are lower, i.e. it is an affordability issue.
- Users with LTE smartphones that do not have Voice over LTE (VoLTE) could get data connectivity but cannot make voice calls if there is only 4G coverage. Without VoLTE voice calls must fall back to circuit switched connectivity (circuit switched fall-back – CSFB) on GSM or 3G (HSPA). Around 80% of handsets in use in Malaysia are LTE smartphones. However, as of July 2019 only 35% of LTE smartphones are VoLTE enabled and this figure is considerably lower in rural areas. This means an operator who builds out 700MHz LTE in rural areas but does not have good 2G or 3G coverage in those rural areas could not provide voice telephony service to over 65% of people in rural areas.

In order to properly serve rural users operators need to have GSM or 3G (HSPA) coverage in parallel with 700MHz coverage. Only Celcom, DiGi, and Maxis have extensive rural coverage with 900MHz. [redacted]

Guaranteeing quick and wide deployment of 700MHz in rural areas

The rapid and wide roll-out of rural coverage requires large financial resources and organisational capabilities. The capability of operators to deploy the 700MHz spectrum for the benefit of Malaysia can be assessed by looking at their existing number of cell sites and their annual capex.

- [redacted]
- Secondly, we need to look at the financial capability of the operators. A good way of measuring their ability to fund the 700MHz roll-out is their existing annual capex as well as capex as a percentage of revenue.
  - [redacted]
  - [redacted]Operators which do not have sufficient scale in terms of revenue would be unable to generate enough revenue to achieve a return on the large investment required to deploy the 700MHz spectrum on thousands of sites in a short period. The capacity to sustain investment can be gauged by looking at capex as a percentage of revenue. A capex / sales figure below 20% is sustainable[redacted]
- The analysis provides evidence that only three operators in Malaysia have the financial strength to fund a wide coverage roll-out of the 700MHz spectrum in a short period of time. It is of course possible for smaller operators to raise the finance to deploy the 700MHz widely is rural areas. However the business case is weak and therefore this is an unlikely scenario. If MCMC was to assign 700MHz spectrum to sub-scale smaller operators, MCMC would be taking a great risk that

this valuable national resource is not deployed to deliver the rural connectivity objectives.

[redacted]

2.3.8 Conclusion

In the introduction of the PI document, MCMC states: *"In light of the growing demand for data and high speed mobile broadband services and to support new technologies, spectrum resources have to be planned and managed efficiently."* MCMC's objective can be best achieved by assigning the entire 700MHz and, i.e. the full 2x45MHz in three blocks of 2x15MHz.

We already know from the above analysis that allocating the 700MHz spectrum to 3 instead of 4 operators would deliver better cost efficiencies and likely lower retail prices. The key question is whether the competition related benefit of having four players with access to 2x10MHz of 700MHz spectrum is greater than the benefit generated by giving 3 players access to 2x15MHz of spectrum.

From the evidence presented above, it is clear that while there are no substantial concerns regarding competition, assigning the available spectrum in 3 blocks instead of 4 blocks would generate substantial socio-economic benefits, deliver the NFCP, improve the 5G investment business case, and result in lower retail prices.

Holding back one 2x5MHz block from this assignment process is highly inefficient because the TCO of operating a single 2x5MHz block is three times as much per MHz deployed compared to a deployment in 2x15MHz. It also does not offer a smooth migration path to 5G.

Exhibit 7: MCMC objectives and 3 block vs. 4 block assignment

MCMC stated objective	Benefit of assigning 3 blocks of 2x15MHz over 4 blocks of 2x10MHz
Average speed for 30 Mbps in 98% of populated areas	50% higher peak data rates resulting in better average speeds
Maximise economic and social benefits	Cost per MHz deployed 30% lower compared to 4 block assignment
Improvement in QoS	Speed is a key determinant of use experienced QoS hence 3 blocks of 2x15MHz results in a better experienced QoS
Enhancement of coverage	A wider band also delivers higher speeds at the cell edge. A wider band means that the point at which the speed become so low as not be useful moves further out. A wider band therefore delivers a coverage benefit.
Provide affordable digital connectivity	Lower cost of assigning in 3 blocks of 2x15MHz will translate into lower retail prices
Encouraging innovation	Wider band allocation result in more efficient deployment of 5G

3 2300MHz award mechanism and timeline

MCMC would like to seek views on the proposed allocation plan for the 2300MHz band and in particular: i) Award mechanism; and ii) Timeline for assignment.

3.1 The 2300MHz award mechanism

3.1.1 MCMC's position

MCMC proposes to assign the 2300MHz nationwide through a comparative tender ("beauty contest") process. A fixed price tender is deemed more suitable than an auction in this case in order to incentivise operators to enhance speeds and QoS.

3.1.2 Celcom's position

Celcom agrees with MCMC's rationale and the conclusion. Celcom is in favour of a spectrum assignment by comparative tender ("beauty contest") where the scoring focuses on 2300MHz coverage roll-out in Malaysia, in support of NFCP objectives, and the credibility to deliver the promised roll-out. The credibility to deliver the promised coverage roll-out should mainly be scored based on historical track record e.g. network rollout, efficiency, capacity to serve, and financial strength e.g. ability to raise funds for network rollout & maintenance and spectrum fees.

In order to ensure that commitments are delivered, there must be substantial penalties backed by performance bonds.

Exhibit 8: Proposed scoring for 2300MHz assignment

Criteria	Weightage
Track record e.g. network rollout, efficiency, capacity to serve	40%
Financial strength e.g. ability to raise funds for network rollout & maintenance and spectrum fees	30%
Roll-out plan	20%
Commitment to network sharing	10%
Total	100%

3.1.3 Discussion and evidence

A comparative tender allows MCMC to score tenders for the 2300MHz spectrum consistent with the goals of the NFCP in respect of achieving the average speed of 30 Mbps by 2023.

The arguments for a comparative tender rather than an auction are similar to those for the 700MHz spectrum and there are further arguments which justify MCMC's and Celcom's view that the assignment should be by means of a comparative tender ("beauty contest") that is evaluated based on criteria as described in Exhibit 8. Therefore, the credibility of the bidder and the realism of the bid must be a key criterium in scoring bids in a comparative tender.

3.2 Timeline for the 2300MHz assignment

3.2.1 MCMC's position

MCMC proposes to start the assignment process for the 2300MHz band in Q4 2019 and to complete by Q3 2020. The 2300MHz band will be assigned by way of SA at the earliest in Q4 2020.

3.2.2 Celcom's position

Celcom suggests assigning the 2300MHz as soon as possible, ideally bringing forward the completion of the assignment to the end of Q1 2020 and making the spectrum available by the end of Q2 2020.

3.2.3 Discussion and evidence

The 2300MHz is a much needed mobile broadband capacity resource. MCMC noted the following: *"As of November 2018, there is a well-developed ecosystem for the 2300 MHz band (3GPP Band 40) with more than 4,000 devices"*. Many 4G smartphones incorporate Band 40 and therefore users would benefit from faster download speeds as soon as the 2300MHz sites are in service.

4 2300MHz optimum block allocation per operator

MCMC would like to seek views on the optimum spectrum block per operator for assignment of the 2300 MHz band.

4.1 MCMC's position

MCMC proposes to package the 90MHz of available spectrum into 9 blocks of 10 MHz each. MCMC has not expressed a view on how this spectrum would be grouped into larger blocks.

4.2 Celcom's position

The 2300MHz has an advantage over other bands used for mobile broadband. The 3GPP 5G specification for this band (n40) allows for a deployment of up to 100 MHz in a single radio which generates excellent cost efficiencies. A good balance of cost efficiency and download speeds on the one hand versus impact on competition or the other hand would be to allocate the 2300MHz band in one block of 50MHz and one block of 40 MHz.

An alternative, though not as efficient from a cost and speed perspective, would be to allocate the band in three blocks of 30 MHz each. Anything less than 30 MHz would fail to take advantage of the benefit of 3GPP specification for 5G in this band.

4.3 Discussion and evidence

4.3.1 Introduction

In the hands of Malaysian mobile operators the 2300MHz band will become an important capacity band for 4G and 5G.

The first handsets and other devices with 2300MHz 5G-NR is expected to appear on the market starting 2022 or earlier. In other words we are at a technology life-cycle juncture where 4G may start to decline and 5G arrives. The transition from 4G to 5G is different from the transition from 3G to 4G precisely because from the start the 2300MHz network will be built with 4G/5G radios.

Because 5G offers a better spectral efficiency compared to 4G, operating the 2300MHz in 5G will yield a lower cost per bit. Operators are incentivised to promote 5G 2300MHz devices over 4G devices because they get more capacity out of each MHz of 2300MHz spectrum. For this reason within three to five years of 5G introduction in this band, 5G traffic is likely to exceed 4G traffic in this band. The 2300MHz band licence duration is likely to be at least 20 years. This means that over the term of the licence period the band will be mainly used for 5G and therefore the analysis of the optimum block assignment should focus on:

- the transition from 4G to 5G; and
- the efficiency gains from 5G in the 2300MHz band.

4.3.2 Technical possibilities

A key benefit of 5G is its ability to deliver fibre-like speeds. This is only possible in a wide band allocation using massive MIMO. In this context an important difference between the 4G 3GPP specification (3GPP band 40) for the 2300MHz and 5G (3GPP band n40) is the channel bandwidths:

- The supported channel bandwidths for band 40 (2300MHz 4G) are 5, 10, 15 and 20 MHz.
- The supported channel bandwidths for band n40 (2300MHz 5G) are 5, 10, 15, 20, 25, 30, 40, 50, 60, 80, and 100 MHz.

The ability to support a wide band is an important benefit of 5G over 4G. Deploying in a wide band allows operators to a) reduce the cost per MHz deployed and b) increase speed. Therefore the objective of the assignment of 2300MHz should be assigned as wide block as possible, subject to the impact on competition.

The 2600MHz FDD (4G band 7, 5G band n7) is specified only in channel bandwidths of 5, 10, 15 and 20MHz, i.e. the maximum bandwidth is 20 MHz. This means the 2300MHz offers an efficiency benefit compared to 2600MHz band, but only if it allocated in a wider band:

- Allocating the 2300MHz band should result in better speed and lower cost per MHz than what can be delivered in the 2600MHz band, but this is only possible if at least 40MHz of 2300MHz spectrum are allocated to an operator. This can be illustrated by comparing the downlink capacity. The 2300MHz is TDD spectrum. Typically 2/3rd of the traffic is in the downlink. Therefore a 40 MHz allocation provides 40 MHz x 2/3rd = 26.7 MHz of downlink capacity. This is more than the 20 MHz maximum downlink capacity in the 2600MHz FDD band.
- If the 2300MHz spectrum block size is allocated in 30 MHz wide blocks, then the downlink capacity is no better than that of the 2600MHz band. The calculation is 30 MHz x 2/3rd = 20 MHz, i.e. the same as for a 2x20MHz allocation in the 2600MHz bands
- If the 2300MHz spectrum is allocated with less than 30 MHz per block, then the capability is lower than 2x20MHz of 2600MHz spectrum. This would be a retrograde step failing to take advantage of potential cost efficiency and not leveraging the speed benefit of a wider bad allocation.

Carrier aggregation can overcome speed limitations due a narrow band assignment. However, this is not as good as having a wider channel because if this is done with carrier aggregation, then:

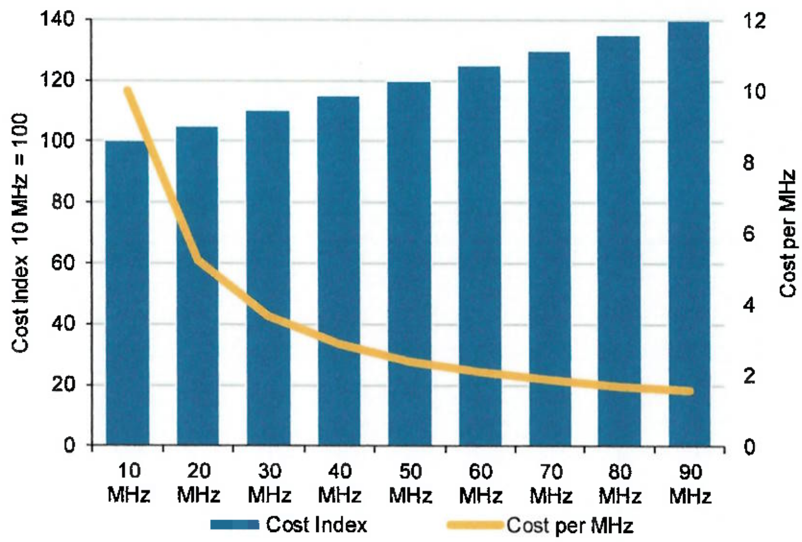
- the cost is higher;
- there is an overhead which leads to an inefficiency; and
- only a few carrier aggregation scenarios are supported by existing smartphones.

4.3.3 Cost efficiency

While 700MHz spectrum offers a channel width of 20 MHz requiring one radio to deploy 2x20MHz, in contrast the channel bandwidth for 5G in the 2300MHz band is specified up to 100 MHz. Therefore the cost efficiency of allocating a wider band is far greater in the 2300MHz band which makes it even more compelling to assign the spectrum in wide blocks of at least 40MHz.

Exhibit 9 below shows the estimated total cost of ownership (TCO) from 10 to 90 MHz in 10MHz steps and the resulting TCO per MHz. The TCO per MHz deployed in a 50 MHz wide assignment is 76% lower compared to the TCO per MHz in a 10 MHz deployment. The cost efficiency is evidence that an allocation of larger blocks to fewer operators is, from a cost efficiency view-point, much better than allocating 10 MHz blocks to many operators.

Exhibit 9: 2300MHz cost efficiency depending on width of band allocation



Source: Coleago, Celcom analysis

Without these cost efficiencies it would be impossible to provide affordable 5G enhanced Mobile Broadband (eMBB) services. The economics of 5G deployment in a wide band is the key ingredient in lowering the production cost per bit. This means operators can offer consumers ever larger data bundles without price increases. The benefit to consumers is a lower cost per Gbyte which is significant because mobile broadband usage per smartphone is increasing.

That operators will not generate more revenue from 5G eMBB is not a mere hypothesis; evidence shows that where operators have launched 5G services, consumers do not pay more but benefit from larger data bundles and faster speeds. Prices for 5G packages are not only not higher than for 4G, but also offer larger data volumes and of course high download speeds. In April 2019, mobile operators in Korea announced tariffs for 5G mobile. Depending on the tariff plan, in some instances 5G plans are cheaper than 4G plans. In early 2019 AT&T in the USA announced a 5G plan at rate of US$ 4.67 per GB compared to US$ 5 per GB for 4G.

Exhibit 10: 5G vs. 4G data pricing in Korea

	Package Type	5G			4G		
		Tariff KRW	Data pack	Limit after out of pack	Tariff KRW	Data pack	Limit after out of pack
LGU+	Entrance	55,000	9GB	1Mbps	55,900	6.6GB	3Mbps
	Middle	75,000	150GB	5Mbps	74,800	16GB	3Mbps
	High	85,000	Unlimited	Unlimited	88,000	30GB	3Mbps
	Premium	95,000	Unlimited	Unlimited	110,000	40GB	3Mbps
SKT	Entrance	55,000	8GB	1Mbps	50,000	4GB	5Mbps
	Middle	75,000	150GB	5Mbps	69,000	100GB	5Mbps
	High	95,000	Unlimited	Unlimited	79,000	150GB	5Mbps
	Premium	125,000	Unlimited	Unlimited	100,000	Unlimit.	n/a
KT	Entrance	55,000	8GB	1Mbps	49,000	3GB	1Mbps
	Middle	80,000	Unlimited	Unlimited	69,000	100GB	5Mbps
	High	100,000	Unlimited	Unlimited	89,900	Unlimit.	5Mbps
	Premium	130,000	Unlimited	Unlimited	n/a	n/a	n/a

Source: Operator websites

To deliver high speed 5G eMBB and not charge more for it, it is essential that operators achieve a lower cost per bit. This can only be realised if operators have access to a wide band allocation. Hence Celcom suggests allocating the 90 MHz of the 2300MHz spectrum as one block of 40 MHz and one block of 50 MHz would be best. Allocating the spectrum in anything less than 30 MHz wide block would be highly inefficient.

4.3.4 Download speeds

A wider band allocation improves the user experience

The wider the band the higher the peak data rates. The peak data rate increases in proportion to the bandwidth and there is also a small trunking efficiency effect of a wider channel. This leads to the conclusion that wider band assignment, say 50 MHz instead of 10 MHz, produces a better user experience. This is the same rationale as for the 700MHz band.

A wide band allocation is required to sustain growth in data traffic

[redacted]

This is evident that there is enormous pressure on network resources. It is economically impossible to satisfy demand from customers without additional spectrum. Given its large customer base, Celcom requires a wide band assignment simply to continue to deliver what its customers expect. Without additional spectrum, there will be network congestion and data traffic will slow down to unacceptable low levels. High speed and low latency are an essential element of 5G and hence a wide band allocation is also essential for Celcom to deliver the 5G user experience.

[redacted]

4.3.5 Maximising value creation from the use of 2300 MHz spectrum

Spectrum is a scarce resource. Therefore most regulators are guided by the principle of efficient use of spectrum. Efficiency means that spectrum should be assigned to those operators who create the most value from it. In a competitive market value means value for consumer because competition will eliminate the produce surplus of spectrum.

We have already explained that a wide band assignment of 40 or 50 MHz is preferred. This means only two operators would get access to this capacity spectrum to serve their customers. Therefore it is useful to understand which mobile networks in Malaysia are good at creating value from their spectrum and have a greater need for spectrum.

Customers pay for mobile services because it is of value to them. Therefore mobile operator service revenue is a good proxy for value creation. Mobile operator service revenue is also a good proxy for the amount of traffic carried by an operator. Operators who generate a high revenue per MHz of spectrum assigned create more value per MHz of spectrum held compared to operators who generate a lower revenue per MHz of spectrum held by them. Operators with a high revenue per MHz also have a high traffic per MHz, i.e. they use spectrum more efficiently compared to operators with a low revenue per MHz.

[redacted]

[redacted]

4.3.6 Impact on innovation

As stated above, the 2300MHz spectrum is relevant for 5G. If an operator holds 40 or 50 MHz, the operator could deploy both 4G and 5G in the same band using the same radio. An operator with 50 MHz would initially run the following configuration:

- 4G in 20 MHz, the maximum possible in the 3GPP specification for 4G (LTE) in this band, which is immediately useful for customers with Band 40 LTE devices;
- 5G in 30 MHz, taking advantage of the wide band specification for 5G, and starting to sell 5G devices likely with unlimited data plans and very high access speeds.

This encourages innovation because operators have an incentive to equip their customers with 5G capable devices, including 5G MYFI devices and 5G smartphones. 5G MYFI devices would play an important part in delivering the 30 Mbps objective of the NFCP in areas where there is no fibre, including many rural small towns and villages.

The simultaneous 4G/5G use of the 2300MHz band can be done in one radio and therefore both capex and opex are low. However, to operate efficiently in 4G and 5G, an operator would need at least 30 MHz.

In contrast, an assignment of 20 MHz or less makes a transition to 5G less likely. For an operator who has been assigned only 20 MHz of 2300MHz spectrum this is immediately useful to customers with 4G devices which incorporate this band. The operator would be likely to operate in LTE only and would not sell 5G devices. The reason for this is that splitting such a small amount of spectrum between 4G and 5G does not result in a good user experience for either 4G or 5G enabled customers. The operator will continue to use the band for 4G for many years and only switch to 5G when all legacy 4G devices have been replaced by 5G devices.

Due to the need for synchronisation of adjacent TDD blocks, the time slot for 5G would have to be based on 4G which is not optimal. However solutions to this issue are being worked on and as the number of 5G users versus 4G users increases, the entire band will become a 5G capacity band.

[redacted]

[redacted]

[redacted]

4.3.8 Effective deployment of 2300MHz spectrum

Achieving average download speeds of 30 Mbps targeted by the NFCP is not a problem in urban areas where fixed broadband connectivity is good. To achieve the goal of delivering an average speed of 30 Mbps to 98% of the population requires substantial investment in rural connectivity. The deployment of 40 or 50 MHz on existing cellular sites in rural areas would bring Malaysia close to the target with the least investment, i.e. it would be highly efficient from an economic view-point.

Building new sites is costly and takes time, and therefore to deploy the 2300MHz spectrum as quickly and as widely possible what matters are the existing cell sites. There are only three operators in Malaysia which provide good coverage in rural areas, namely Celcom, Maxis and DiGi. The operators could deploy the spectrum on their existing sites in locations where this is most needed, i.e. in rural areas. If the spectrum is in the hands of the three operators, these operators will compete to provide 5G access in rural areas as quickly as possible. In contrast assigning the spectrum to an operator with little rural presence does nothing for competitive mobile broadband service provision in rural areas.

4.3.9 Impact on competition in rural areas

As noted in 4.3.8 only three operators are in a position to deploy the spectrum quickly in rural areas of Malaysia. Therefore assigning spectrum to operators with a limited presence in rural Malaysia would not contribute to competitive service provision in rural areas.

4.3.10 Impact on competition in urban areas

Malaysian smartphone users have some of the world's highest data usage rates. Mobile operators with large market shares experience very high traffic densities. For the three largest operators, it has become difficult to serve the traffic in dense urban areas. The cost of providing additional capacity without access to considerably more spectrum is so high as to make it uneconomic. In other words without a large assignment of TDD spectrum, the three largest operators will become capacity constrained in urban areas.

In a capacity constrained situation there is no incentive for these operators to drive down prices and offer larger data bundles. The marginal increase in revenue would be low or zero. The marginal cost of providing capacity without a wide band assignment in 2300MHz is such that the business case does not make financial sense. This means data bundles will be smaller than they otherwise would be and the average retail price per Gbyte would be higher.

To remove this supply constraint and incentivise the three largest operators to further drive down prices or increase the size of the data bundles, needs to allocate the 2300MHz spectrum to mobile operators with extensive rural coverage.

4.3.11 Conclusion

In the introduction of the PI document, MCMC states: *"In light of the growing demand for data and high speed mobile broadband services and to support new technologies, spectrum resources have to be planned and managed efficiently."* MCMC's objective can be best achieved by allocating the 2300MHz spectrum in one block of 50 MHz and one block of 40 MHz.

The NFCP sets out, among others, the target of an average speed of 30 Mbps in 98% of populated areas by 2023. In rural small towns and villages this target is challenging to achieve. Allocating the 2300MHz in two wide blocks would enable operators to deliver this target with 5G technology. Allocating it a less than 30 MHz wide block would not be helpful in reaching this objective.

Exhibit 13: MCMC objectives & a wide band assignment of 2300MHz band

MCMC stated objective	Benefit of assigning a wide band
Average speed for 30 Mbps in 98% of populated areas	Assigning the spectrum in a 40 and 50 MHz block would enable operators to deliver at areas where there is a lack of wired broadband.
Maximise economic and social benefits	The cost per MHz deployed in a 50 MHz wide block is 76% lower compared to the cost per MHz in a 10 MHz block.
Improvement in QoS	Speed is a key determinant of user experienced QoS and the wider the band allocation the higher the speed.
Enhancement of coverage	2300MHz spectrum is not ideal to provide wide area coverage (this is best done with 700MHz spectrum). However in a mobile broadband world what matters is speed coverage, i.e. the coverage area where Gbps access speeds are available. Speed coverage improves with a wide band allocation. Gbps 5G access in underserved areas can be delivered with the allocation of 40 or 50 MHz of 2300MHz spectrum.
Provide affordable digital connectivity	Allocating the spectrum in a 40 or 50 MHz block reduces operator costs to deploy the spectrum by up to 76%. Ultimately this will translate into lower retail prices, i.e. delivering affordable digital connectivity.
Encouraging innovation	With an allocation of less than 30 MHz the introduction of 5G in this band is likely to be delayed by at least 6 years.

5 2600MHz award mechanism and timeline

MCMC would like to seek views on the proposed allocation plan for the 2600 MHz band and in particular: i) Award mechanism; and ii) Timeline for assignment.

5.1 The 2600MHz award mechanism

5.1.1 MCMC's position

MCMC is considering the reassignment of the 2600MHz band through SA based on actual utilisation. This will involve direct conversion of current AAs held by Maxis, Celcom, U Mobile, Digi, Unifi (TM/Webe) and YTLC, to SA.

MCMC notes that "*The bandwidth of 20 MHz for deployment of LTE technology is considered ideal since the 2600 MHz band is used primarily as a capacity band.*"

5.1.2 Celcom's position

Celcom supports and applauds MCMC's intention to reassign the 2600MHz band based on current actual utilisation via direct conversion of current Apparatus Assignments (AA) to Spectrum Assignment (SA) as it is deemed ideal and practical to ensure good customer experience and no service disruption. MCMC's proposal is a practical approach to ensure service continuity and, in time, enables operators to migrate the band to 5G-NR.

5.1.3 Discussion and evidence

MCMC recognises that the 2600MHz band is a key capacity resource for LTE: *"The 3GPP Band 7 is seen as an important band to provide additional capacity to mobile broadband networks particularly in dense urban areas where there is likely to be congestion."* In fact there is congestion today. As of July 2019, the average Celcom smartphone customer consumed [redacted] per month. This means Malaysian smartphone use is among the world's highest. Not only is data traffic growing but the growth is accelerating as evidenced by [redacted] which shows the monthly data traffic in Celcom's network. In the 12 months period July 2018 to July 2019 data traffic in Celcom's network grew by [redacted]

[redacted]

[redacted]

All of Celcom's 4G smartphone customers have handsets which incorporate 3GPP Band 7. As of today, the 2600MHz band is the only band entirely dedicated to 4G. Therefore this band is critical to maintaining network performance. Consumer welfare is one of MCMC's key concerns. Allocating less than 2x20MHz would have a serious negative impact on mobile users in terms of the experienced speed.

Celcom and other operators with 2x20MHz of 2600MHz FDD spectrum already deploy LTE in 2x20MHz, i.e. the equipment is in service. MCMC rightly states that *the bandwidth of 20 MHz for deployment of LTE technology is considered ideal since the 2600 MHz band is used primarily as a capacity band.* The 3GPP specification for Band 7 (4G) and Band n7 (5G) allows a maximum channel bandwidth of 20MHz. Using the band with single radio serving 2x20MHz maximises the deployment efficiency both for 4G and later 5G. Allowing Celcom to retain its existing use of 2x20MHz of Band 7 is consistent with MCMC's objectives because it maximises economic efficiency and it delivers the best possible peak throughput in this band. In addition, there is service continuity without any disruption.

In contrast, if there were to be a reduction of the 2x20 MHz currently used by Celcom's customers and also all its MVNO customers, this would require a significant site densification programme to offset the loss of capacity. This is highly inefficient because the value of the existing 2600MHz would be reduced and there would be additional capex and network opex. As a result of higher costs, retail prices would also be higher than they otherwise would be.

Secondly, assuming that new sites can be found high density traffic areas, it would take up to two years to build these sites. Therefore compensating a potential reduction in 2600MHz spectrum holdings with site densification is not a realistic prospect in the short term. Consumers would suffer from lower speeds.

5.2 Timeline for the 2600MHz assignment

5.2.1 MCMC's position

The conversion process of the 2600MHz band is expected to commence in the 4th Quarter of 2019 and targeted to be completed by the 2nd Quarter of 2020. The 2600 MHz band will be assigned by way of SA at the earliest in the 3rd Quarter of 2020.

5.2.2 Celcom's position

Celcom seeks an earlier conversion and assignment of the SA i.e. conversion process to be completed by December 2019 and the 2600MHz band to be assigned by way of SA on the 1st of January 2020. [redacted]

[redacted]

[redacted]

Celcom supports and applauds MCMC's intention to reassign the 2600MHz band based on current actual utilisation via direct conversion of current AA to SA as it is deemed ideal and practical to ensure good customer experience and no service disruption. Therefore, Celcom seeks MCMC's consideration to issue the SA for 2x20MHz to Celcom with effective/ start date of 1st January 2020 based on current actual utilization. The confirmation would also give us more certainty to invest further in the band.

5.2.3 Discussion and evidence

As mentioned above, mobile broadband traffic is increasing sharply. In order to cope with the high traffic density, operators need to invest in the latest equipment. However, uncertainty over what spectrum operators will end up with holds back investment. As soon as operators are handed 20 years licences, they are likely to invest in upgrade programmes using innovative technology. Innovation is one of MCMC's objective.

Operators will install MIMO antennae which increases the spectral efficiency, i.e. the capacity per MHz. This means mobile broadband users will experience higher speeds. For example, in 2017 Turkey Vodafone demonstrated 2600MHz TDD with massive MIMO (64x64). The downlink throughput from the base station to the customer's smartphone was improved by 13%.

5.2.4 Conclusion

In the introduction of the PI document, MCMC states: *"In light of the growing demand for data and high speed mobile broadband services and to support new technologies, spectrum resources have to be planned and managed efficiently."* MCMC's objective can be best achieved by assigning the 2600MHz FDD spectrum to those operators who currently use it with SA effective date of 1 January 2020.

Exhibit 15: MCMC objectives & retaining 2x20MHz of 2600MHz spectrum

MCMC stated objective	Benefit of assigning 2600MHz FDD spectrum to current users
Average speed for 30 Mbps in 98% of populated areas	To maintain the current speed for its own customers and MVNO customers, Celcom needs to be assigned the 2x20 MHz it currently uses. An early assignment would enable Celcom to bring forward investment in MIMO enhancements which leads to higher speeds.
Maximise economic and social benefits	It would be economically inefficient to reduce the spectrum currently deployed by Celcom because there needs to be reinvestment to compensate for the loss without which, it would create a substantial reduction in user experienced speed. In addition, any SA effective date later than 1 January 2020 will impose serious service disruption/ quality degradation to the current subscribers.
Improvement in QoS	Speed is a key determinant of use experienced QoS and retaining the use of 2x20 MHz maintains quality of service.
Provide affordable digital connectivity	Assigning less than 2x20 MHz to Celcom would push up Celom's costs and reduce our ability to reduce prices.
Encouraging innovation	MIMO technology is a 5G innovation which is also available in 4G. An early assignment would enable Celcom to bring forward investment in this innovation and prepare for 5G.

6 Interference between 2600MHz FDD and TDD

MCMC seeks suggestions on approaches to mitigate interference between FDD and TDD blocks to facilitate efficient spectrum utilisation in the 2600MHz band.

6.1 Interference mitigation between 2600MHz FDD and TDD blocks

6.1.1 MCMC's Position

MCMC is considering the reassignment of the 2600 MHz band through SA based on actual utilisation and seeks views on approaches to mitigate interference between FDD and TDD blocks. 2600MHZ FDD (3GPP band 7) and 2600MHz TDD (3GPP band 38) spectrum has previously been allocated and deployed in Malaysia. MCMC is therefore aware of the potential interference issues associated with 2600MHz FDD and TDD coexistence within Malaysia and at international border areas.

6.1.2 Celcom's Position

Celcom has deployed 2600MHz FDD (3GPP band 7) as its main LTE capacity resource to support the existing LTE coverage layer using 1800MHz and future wide area 700/900MHz LTE coverage bands. The Celcom 2600MHz LTE network has been deployed using best industry practice and international guidelines to ensure any interference issues between 2600MHz FDD and TDD systems are minimised.

3GPP band 7 FDD and band 38 TDD deployments are now widespread across the world. Industry best practice/guidelines for 2600MHz FDD/TDD implementation and coexistence are now well documented in several ITU/APT/CEPT technical reports. FDD – TDD interference issues can be minimised if the industry follows these best practice guidelines and recommendations.

5MHz guard bands between FDD and TDD spectrum blocks should be maintained to minimise interference issues on adjacent channels.

There is the possibility to deploy 5G in 40MHz of TDD using a subset of 3GPP band n41 rather than band n38 which should be considered as this offers a more efficient wider 5G carrier implementation. In order to coexist with band 7/n7, this will require vendors to customise filtering in the band n41 radio units which we understand will be possible.

6.1.3 Discussion and evidence

Looking forward there is likely to be much more use of 2600MHz TDD for mobile broadband services. This is as a result of wider device diffusion and the potential of a 40MHz wide channel within the band 7 duplex gap, delivering significant downlink capacity for mobile broadband services.

There are five main areas for a network operator to consider in order to minimise and mitigate interference between 2600MHz FDD and TDD systems:

- TDD Synchronisation – e.g. compliance to IEEE 1588 v2[8] ensuring time synchronisation and operator coordination using same time slots for uplink/downlink;
- Guard bands – maintain 5MHz guard bands between FDD and TDD spectrum blocks;
- Filtering – built in radio equipment/front end filters complying with block edge mask recommendations;

8 APT/AWG/REP-60 March 2015

celcom

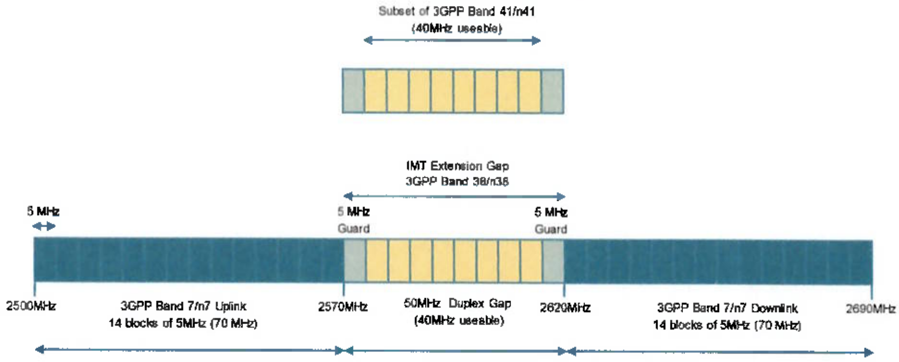
- Antenna separation at co-located sites – vertical separation of antennas where required; and
- International Border area buffer zones – regulatory/industry coordination.

3GPP band 7 FDD and band 38 deployments are now widespread across the world and best industry practice and guidelines for all of the above areas are well documented in several ITU/APT/CEPT technical reports. These include:

- APT report on 2.6GHz frequency arrangements, national allocations and assignments for IMT[9]
- APT report on network synchronisation technologies in radio access networks for IMT TDD systems[7]
- ECC report giving practical guidance for TDD network synchronisation[10]
- ECC report on coexistence between mobile systems in the 2.6 GHz frequency band at the FDD/TDD boundary[11]
- ECC report which considers terminal to terminal interference and associated block edge masks[12]

The deployment of 2600MHz TDD in a 40MHz wide channel can be accommodated using band 3GPP band 38/n38[13] or in a 40MHz subset of band 41/n41. This is illustrated in the exhibit below.

Exhibit 16: 3GPP band 7/n7, 38/n38 and subset of band 41/n41



Source: 3GPP and CEPT Report 2

The advantage of deploying 40MHZ of TDD within a subset of band 41/n41 is that 3GPP specifies 5G carrier bandwidths over 20MHz (up to 100MHz) for this band whereas with band n38 the maximum carrier bandwidth is only currently specified up to a maximum of 20MHz[14]. This is likely to make 5G deployment of 40MHz in band 38 more expensive and less efficient compared to deploying in a subset of band n41 where a full 40MHz carrier can be accommodated in a single radio unit.

However, in this situation the band n41 radios will require internal radio filters to be customised to limit the bandwidth to 40MHz in order not to interfere with FDD band 7/n7, as the standard n41 radio bandwidth will be 194Mhz. Celcom understands from the vendor community that this will be achievable.

9 APT/AWG/REP-32 Sept 2012
10 ECC Report 216 August 2014
11 ECC Report 119 June 2008
12 ECC Report 131 January 2009
13 'n' refers to 5G new radio band 3GPP prefix
14 3GPP specification TS 38.104

7 Spectrum pricing and fees

MCMC would like to seek views on the appropriate range (per MHz) for Spectrum Assignment fees (i.e Price Component "PC" and Annual Fee Component "AFC") and the rationale for the proposed fees, for the following spectrum bands: i) 700 MHz; ii) 2300 MHz; and iii) 2600 MHz.

7.1 MCMC's position

MCMC did not propose specific prices. However, in its discussion with regards to the auction versus comparative tender award process MCMC rightly stated that an "*auction process may inflate the spectrum price and may restrict operators' ability to invest in network deployment.*" This statement is particularly relevant because MCMC has stated development objectives which require significant investment.

7.2 Celcom's position

Celcom welcomes MCMC's recognition of the trade-off between spectrum licence fees and network investment. This trade-off is important because mobile operators need to have a viable business case for investment in spectrum, 4G and soon 5G.

All spectrum, used for 4G and 5G mobile broadband, shall spur the development of a country. Hence, a development policy objective is appropriate. The implication for telecoms regulators is to assign as much spectrum as possible, as quickly as possible and as cheaply as possible. Broadly this is the policy adopted in Finland and Sweden, markets in which consumers benefit from excellent mobile broadband services and low prices.

In order to achieve MCMC's development objectives, deploy new frequency bands, and also transition to 5G, operators in Malaysia need to make significant investments:

- Bringing a 30 Mbps average speed to 98% of the population is costly because it requires substantial investment in rural mobile broadband coverage. However, the returns on this incremental investment are likely to be negative, i.e. the overall return on investment of mobile operators would decline.
- The first 5G mobile networks are already in commercial service. To achieve MCMC's objective for speed, innovation, and QoS, Malaysia needs to maximise the use of spectrum for 4G and 5G. 5G requires substantial network investment. Furthermore, the transition to 5G is associated with making new spectrum available for mobile including spectrum in the C-Band (3.3-3.8GHz) and mm wave spectrum (26GHz and above) which requires further investment.

The total cost of spectrum including the PC and the AFC component must be sustainable in relation to mobile operator service revenue. Therefore in determining the PC and the AFC for each band, MCMC must take account of:

- The cost of existing spectrum assignments (SA) for 900, 1800, and 2100MHz spectrum, including the PC and the AFC.
- The PC and AFC for spectrum on the roadmap for the next few years, including the spectrum considered in this PI (700, 2300, and 2600MHz)
- And also future assignment plans for the next five years, for example the C-Band (3.5GHz) and mm wave spectrum (26GHz).

Given Malaysia's digital development policy goals and MCMC's specific objectives, Celcom recommends that the total cost of spectrum, including the annualised cost of the PC and the AFC of spectrum, for all mobile operators should not increase materially.

- In 2019 the total annualised cost of spectrum of all mobile operators amounted to an estimated 4.5% of mobile service revenue.

- If the annualised cost of spectrum were to increase materially this would negatively impact the current economics of mobile broadband service provision in Malaysia.
- Setting the PC and AFC at an amount so that as result the annualised cost of spectrum will exceed 5.0% of total market mobile service revenue will increase the cost of spectrum but to a level where it is likely to remain sustainable. We consider a level of 5.5% as the annualised cost of spectrum as a percentage of revenue as the upper limit of sustainable spectrum pricing.
- If the PC and AFC for new spectrum result in the cost of spectrum to increase to level above 5.5% of industry revenue this is likely to have adverse consequence for 4G and 5G mobile broadband roll-out.

Within this overall envelope, the per MHz upfront fee for the 700, 2300, and 2600MHz band should reflect the relative scarcity of sub-1GHz spectrum and the fact that the 2600MHz is already in use under AA.

Celcom recommends setting the PC for 700MHz spectrum at 30% of the PC which was paid for 900MHz and the PC for 2300MHz spectrum at 90% of the PC for 2100MHz spectrum. However, 2300MHz ratio is higher because Celcom believes it is also useful as the core band for FWA and eventually 5G services. We further recommend that the AFC for 700MHz and 2300MHz spectrum is set at 5% to 10% of the PC.

The AFC can be converted into a PC equivalent using discounted cashflow. The weighted average cost of capital of the mobile operators in Malaysia is around 8% and this is the discount rate to be used. We assume a licence term of 20 years.

- If the AFC is 10% of the PC this is the present value equivalent of 98.2% of the PC. In other words, at 10% of the PC, the AFC almost double the cost of spectrum. This is high, compared for example to European Union countries.
- If the AFC is 5% of the PC this is the present value equivalent of 49.1% of the PC. In other words, at 5% of the PC, the AFC increase the cost of spectrum by nearly 50%.

For the 2600MHz spectrum the consideration for the PC is different. MCMC should take into account that the 2600MHz spectrum is already in use; it is not a new resource but a conversion from AA to SA. Therefore Celcom considers that the PC should be the same as one year's AFC. This puts some value of the conversion from AA to SA but does not cause a financial shock to the mobile industry in Malaysia.

In Exhibit 17 we propose the lower range of the PC and AFC resulting in an annualised spectrum cost to be within 5% of mobile industry service revenue.

Exhibit 17: Spectrum licence fees bottom of range – RM million

Band	MHz	PC	AFC	AFC 20 Year NPV	PC per MHz	AFC per MHz	AFC % of PC
700	90	589	29	289	6.5	0.3	5%
2300	90	315	16	155	3.5	0.2	5%
2600 FDD	140	99	99	975	0.7	0.7	100%
2600 TDD	40	28	28	279	0.7	0.7	100%
Total	360	859	164	1,613			

Note: For the 700MHz and 2600MHz FDD spectrum the amount of spectrum shown is the total. For example, 2x45 MHz of 700MHz spectrum is shown as 90 MHz. This allows us to compare the per MHz fee for FDD and TDD spectrum.

The table shows:

- The total amount of spectrum that will be assigned in each band. For the 700MHz and 2600MHz FDD spectrum the amount shown is the total. For example, 2x45

MHz of 700MHz spectrum is shown as 90 MHz. This allows us to compare the per MHz fee for FDD and TDD spectrum

- The PC for the total amount of spectrum in each band.
- The AFC for the total amount of spectrum in each band.
- The Net Present Value (NPV) equivalent of the AFC assuming a 20 year licence term and using a discount rate of 8% (weighted average cost of capital - WACC for mobile operators in Malaysia). We can see that under this scenario the NPV of the AFC is almost 50% of the PC.
- The column "PC per MHz" shows the PC divided it by the amount of spectrum. The result is the PC per MHz. From that the PC for any spectrum block size can be calculated, for example a 30 MHz block licence.
- The column "AFC per MHz" shows the AFC divided by the amount of spectrum. The result is the AFC per MHz. From that the AFC for any spectrum block size can be calculated.
- The final column shows the AFC as a percentage of the PC. As explained above in this scenario we assume that for 700MHz and 2300MHz spectrum (new mobile spectrum) it is 5% of the PC respectively. For the 2600MHz spectrum we suggest the PC should be the same as one year's AFC.

Exhibit 18 show our proposed upper range of the PC and AFC resulting in an annualised spectrum cost to be within 5.5% of mobile industry service revenue.

The main change is that the AFC is set at 10% of the PC instead of 5%.

Exhibit 18: Spectrum licence fees top of range – RM million

Band	MHz	PC	AFC	AFC 20 Year NPV	PC per MHz	AFC per MHz	AFC % of PC
700	90	589	59	578	6.5	0.7	10%
2300	90	315	32	309	3.5	0.4	10%
2600 FDD	140	151	151	1,478	1.1	1.1	100%
2600 TDD	40	43	43	422	1.1	1.1	100%
Total	360	925	267	2,618			

Note: For the 700MHz and 2600MHz FDD spectrum the amount of spectrum shown is the total. For example, 2x45 MHz of 700MHz spectrum is shown as 90 MHz. This allows us to compare the per MHz fee for FDD and TDD spectrum

Consistent with the need to key the overall cost of spectrum to a sustainable level, PC for 700MHz are lower compared to 900MHz and PC for 2300MHz are lower than for 2100MHz as shown in Exhibit 19. [redacted]

Exhibit 19: Proposed PC compared with previous PC

Sub-1 GHz spectrum	900MHz	700MHz	700 / 900 MHz
RM mn per MHz	21.8	6.5	30%
Mid-band spectrum	**2100MHz**	**2300MHz**	**2300 / 2100 MHz**
RM mn per MHz	3.9	3.5	90%

Source: Coleago, Celcom analysis

7.3 Analysis of the cost of spectrum in Malaysia

7.3.1 Amount of spectrum used for mobile

As of July 2019, spectrum used for mobile in Malaysia includes 850MHz, 900MHz, 1800MHz, 2100MHz, 2300MHz TDD and 2600MHz FDD.

- The 900, 1800 and 2100MHz Spectrum Assignments were awarded following payment of an PCe for a 15 to 16 year duration and there are substantial AFC
- The 850MHz, 2300MHz and 2600MHz are used under the Apparatus Assignments, i.e. there is an AFC to use the spectrum on radio sites.

In 2019, mobile operator is Malaysia used 610 MHz of spectrum as shown in Exhibit 20 below. The table also shows the increase in the spectrum assigned to mobile operators from 2019 to 2021. The new 700MHz and 2300MHz assignments are those stated in the MCMC PI document and this mean by the end of 2020, mobile operators in Malaysia will use 700 MHz of spectrum. The 3500MHz spectrum may be assigned in 2021 and we have assumed that 300 MHz will be assigned. This brings the total amount of spectrum used for mobile to 1,000 MHz. This means that in the period 2019 to 2021 the amount of spectrum used for mobile will increase by 64%. Beyond 2021 it is likely that mm wave spectrum in the 26GHz range will be assigned to mobile (not shown in the table).

Exhibit 20: Spectrum used for mobile in Malaysia

Band		2019	2020	2021
700 MHz	New	0	90	90
850 MHz	Existing	10	10	10
900 MHz	Existing	60	60	60
1800 MHz	Existing	150	150	150
2100 MHz	Existing	120	120	120
2600 MHz FDD	Existing	140	140	140
2600 MHz TDD	Existing	40	40	40
2300 MHz	Existing	90	90	90
3500 MHz	New	0	0	300
Total MHz		610	700	1,000
Increase % from 2019			15%	64%

Source: MCMC and Celcom's estimate for 3500MHz spectrum

7.3.2 Evolution of mobile service revenue in Malaysia

Mobile service revenue grew by 3.6% in 2018 to reach an estimated RM 23.5 bn. However, the result for the first half of 2019 shown that mobile service in 2019 will be slightly lower than in 2018, largely due to the reviewing of some national roaming arrangements which reduces revenue for Celcom and Maxis. 2019 mobile service revenue is forecast to be [redacted] Thereafter mobile service revenue is expected to remain flat which is consistent with the trend in most countries as evidence in chapter 7.4 below.

We can then compare the increase in spectrum used for mobile services with the increase in mobile service revenue, as shown in [redacted]. Clearly the amount of spectrum is increasing much more than revenue. As a result mobile service revenue per MHz of spectrum declines as shown in [redacted]. Even if the 3500MHz assignment is delayed to 2022, this does not change the conclusion that revenue per MHz is declining substantially.

Given that the revenue per MHz of spectrum deployed by mobile operators will decline substantially, the fees per MHz of spectrum used must also decline substantially. If not, the cost of spectrum in relation to revenue generated from the use of spectrum will increase just at the point in time when mobile operators are facing the high cost of delivering the NFCP as well as the investment in 5G.

[redacted]

[redacted]

7.3.3 The cost of spectrum in relation to mobile service revenue

Ultimately the entire mobile business in Malaysia is driven by market demand, i.e. how much consumers and businesses are willing to pay for mobile services. This is the mobile service revenue earned by all of Malaysia's operators. How much operators can pay for spectrum is linked to the revenue generated from the use of that spectrum. It is therefore reasonable to assess the cost of spectrum in relation to mobile operator service revenue.

There are two components to the cost of spectrum, namely PC and AFC. If we want to calculate the annual cost of spectrum, we need to convert the PC into an annualised equivalent.

- The PC for the 900, 1800, and 2100MHz licences (SA) acquired by Malaysian operators is still sitting in their balance sheets. Over the term of the licence, for example 15 years, the cost of the spectrum licence is amortised, i.e. each year 1/15% is passed as a cost though the income statement. The longer the licence period, the lower the annualised cost of spectrum.
- Fees paid for spectrum in the past need to be financed by loans or by shareholders. This is the weighted average cost of capital (WACC). The higher the WACC the higher the annualised cost of spectrum.

We use the licence duration and the WACC in an annuity formula as shown in Exhibit 23. As explained above, the annuity formula takes account of the amortisation of the licence and the cost of capital to finance the PC.

In Malaysia, there is also a substantial AFC which must be added to the annualised cost of PC in order to obtain the total annual cost of spectrum. The total annual cost of spectrum can then be compared with the annual industry revenue.

The annualised cost of spectrum methodology provides a metric which allows MCMC to compare the price of spectrum relative to the size of the mobile industry in Malaysia. The key advantage of this approach is that it is forward looking rather than using benchmarks from past auctions or from other countries. Using the annualised cost of spectrum methodology, MCMC can look at the spectrum assignment roadmap in Malaysia and assess what level of spectrum pricing would be sustainable in the context of the mobile industry in Malaysia.

Exhibit 23: Annuity calculation formula

The annuity calculation formula to convert PC into an annualised cost of spectrum
Annualised cost = PC x cost of capital / (1 - (1 / (1 + cost of capital)) ^ years of licence term)
Note: The cost of capital is the weighted average cost of capital (WACC)

Source: Coleago

Exhibit 24 shows the calculation for the annualised cost of spectrum in Malaysia. This calculated at industry level.

- The column "MHz assigned" shows for each frequency band the total amount of spectrum assigned to all operators in Malaysia.
- Next we show the licence duration in years. The 850 and 2600MHz spectrum is assigned under AA and hence there is no licence duration.
- The column "PC paid" show the PC paid by mobile operators at the time of the licence award.
- The "annualised upfront fee" column shows the PC converted to an annualised equivalent using the annuity formula shown in Exhibit 23.
- The "AFC" is for AAs is the estimated amount that will be paid by mobile operators to MCMC in 2019 and for SA's it is the AFC for the SA.
- The final column is the sum of the two preceding columns. This is the total annualised cost of spectrum.

The total cost of spectrum to mobile operators in Malaysia in 2019 is estimated at RM 992 million.

Exhibit 24: Annualised cost of spectrum Malaysia 2019

Band	MHz assigned	Licence duration years	PC paid RM mn	Annualised PC RM mn	AFC RM mn	Total annualised cost RM mn
850	10	n/a	0	0	18	18
900	60	15	1,309	153	113	266
1800	150	15	1,426	167	123	289
2100	120	16	474	54	200	254
2600 FDD	140	n/a	0	0	151	151
2600 TDD	40	n/a	0	0	15	15
Total	520					992
% of mobile service revenue						4.5%

Source: Coleago, Celcom analysis
Note: 850 and 2600 are AA which only have an AFC. The estimated AFC is shown in the column "AFC". The other band are SA for which an PC was paid and also have an AFC. We have excluded cost for 2300MHz due to non-availability of information.

As explained above, in 2019, mobile service revenue will be an estimated [redacted]. However, around [redacted] of this revenue is paid out in non-spectrum related regulatory fees. The net revenue available to mobile operators in 2019 is estimated at [redacted]. This is the amount used to assess the cost of spectrum against. The total cost of spectrum in 2019 is estimated at [redacted]. This means in 2019, the annualised cost of spectrum used by mobile operators is around 4.5% of mobile service revenue.

7.3.4 Determining the price range for 700, 2300 and 2600 SAs

We explained that in setting the prices for spectrum, MCMC must take account of the revenue generated from the use spectrum. In the next two to three years spectrum in 700, 2300, and 3500MHz will be added to mobile operator's holdings. The spectrum used by mobile operators will increase from 610 MHz in use today to 1,000 MHz, i.e. an increase of 64%.

In contrast mobile operator revenues are forecast to remain flat during the next few years. This means the total cost of spectrum as a percentage of revenue cannot substantially increase beyond its current level of 4.5%. A level for 5% to 5.5% may be sustainable. Sustainable means that the cost of spectrum does not jeopardise the delivery of the NFCP objectives and timely introduction and wide roll-out of 5G.

There are several aspects to be considered:

- The total annualised cost of spectrum, including PC and AFC should be set in such a manner as not to increase the total annualised cost of spectrum to operators;
- The balance between the PC and AFC; and
- The relative price per MHz of 700MHz spectrum (sub-1GHz) vs. 2600MHz spectrum vs. 2300MHz spectrum.

The AFC can be converted into an PC equivalent and vice versa. Operators can calculate equivalence between the two in present value terms. However, there are a number of factors to consider when striking a balance between the two components.

First, let's consider whether there is a need for an AFC for the use of spectrum.

- The AFC is required to cover the cost spectrum management and other important spectrum related activities of the MCMC.
- An AFC ensures that there is a cost to holding spectrum. Operators have an incentive to hand back spectrum that that is not used. Therefore, an AFC fosters efficient use of spectrum.

Secondly, we explore the rationale for an PC.

- Charging a PC for spectrum is the best lever MCMC has in order to ensure that only operators who have sufficient scale, financial resources and network resources will acquire the spectrum. These operators are in a position to leverage the value of the spectrum for the benefit of the country.
- An PC acts as a barrier to bidders with speculative, highly uncertain business cases. With very low PC it is easier for an operator to raise the finance to acquire a spectrum licence based on a business case that relies on assuming new forms of revenue that arise in the medium to long-term future. There is lot of uncertainty that comes with such a business case. While this is risky for investors, it is also risky for MCMC because in the short term the spectrum will be used less efficiently than it otherwise would be, and it is highly uncertain that spectrum will be used more efficiently in the longer term.

Thirdly, as regards the relative pricing of 700MHz vs. 2300MHz and 2600MHz spectrum, sub-1GHz spectrum should be priced higher than mid band spectrum.

- Pricing needs to take account of the relative scarcity. There is far less sub-1GHz spectrum available than mid-band spectrum. Therefore on a per MHz basis, the 700MHz spectrum should be priced higher than the 2300MHz or 2600MHz spectrum.
- On a per MHz the annualised cost of 900MHz is 2.3 times higher than the annualised cost of 1800MHz spectrum and 2.1 times higher than 2100MHz spectrum.
- The 2600MHz spectrum is already in use, and a spectrum pricing which suddenly imposes a large additional cost on operators is disruptive and should be avoided.

Considering these issues, Celcom suggests that MCMC adopts the spectrum prices shown in Exhibit 26 below.

- 700MHz spectrum: Celcom recommends that on a per MHz basis, the PC is set at 30% of the PC for 900MHz spectrum and the AFC at 5% to 10% of the PC. This makes the 700MHz cheaper than the 900MHz spectrum. This is consistent with the fact that revenue per MHz is declining and hence the spectrum licence fee per MHz must decline. A lower licence fee compared to 900MHz it is also consistent with ambitious coverage roll-out objectives to bring mobile broadband to 98% of Malaysian population.
- 2600MHz FDD spectrum: As mentioned above, the 2600MHz FDD spectrum is already in use. Celcom recommends setting the AFC at 50% to 100% of the current cost for operators who has deployed the 2600MHz FDD spectrum. The PC should be equivalent to a one year AFC. If the fees are set comparable to the current annual AA cost, the transition from AA to SA would be cost neutral for operators. This is reasonable because making the transition from AA to SA does not change mobile operator's revenues or costs. However, given that operators will deploy more in new spectrum i.e. 3.5GHz etc, a lower fee per MHz for 2600MHz would be justified, for example 50% of the current AA cost.
- 2600MHz TDD spectrum: Celcom proposes to have the same per MHz price for 2600MHz TDD spectrum as for 2600MHz FDD spectrum. In the short term the eco-system is not as good as for 2600MHz FDD spectrum which would indicate that a lower price may be appropriate. However, an equivalent amount for FDD spectrum does not have the same data capacity. Around 2/3rds of data traffic is in the downlink. Therefore 30 MHz of TDD spectrum produces the equivalent downlink capacity as 2x20MHz (i.e. 40 MHz in total) of 2600MHz FDD spectrum.

- 2300MHz spectrum: The proposed fees for 2300MHz is proposed because Celcom believes it is also useful [redacted]. As a 4G layer, this new spectrum will be used for additional capacity and is able to cater for higher traffic densities and deliver a download speed consistent with the target of the NFCP. The licence fee is therefore proposed to be set to reflect the above uses. This can be achieved by setting the per MHz PC at 90% of what was paid for 2100MHz spectrum and the AFC at 5% to 10% of that.
- As explained above, the annualised cost of spectrum is influenced by the licence duration. At a given PC the longer the licence period the lower the annualised cost of spectrum. Therefore, Celcom suggest that the licence term for all new SA should be 20 years. This is a simple way for MCMC ensuring that the annualised cost of all spectrum holdings remains in a range of 5% to 5.5% of revenue compared to around 4.5% today.

Exhibit 25 below shows the current status of the cost of spectrum to mobile operators (see also Exhibit 24 above). For the Spectrum Assignments, i.e. 900MHz, 1800MHz and 2100MHz we converted the PC into an annualised equivalent using a Weighted Average Cost of Capital of 8% and the licence duration of 16 or 15 years as appropriate. For the Apparatus Assignments (850MHz and 2600MHz) we estimated the annual fees paid by the entire mobile industry. The total annualised cost of spectrum amounts to RM 991.9 million which is equivalent to 4.5% of mobile market revenue.

Exhibit 25: Annualised cost of spectrum – current status (RM million)

Band	MHz	PC	AFC	Annua-lised cost	Annua-lised cost / MHz	% of highest
850	10	0.0	18.0	18.0	1.80	41%
900	60	1,309.2	112.6	265.6	4.43	100%
1800	150	1,426.3	122.7	289.3	1.93	44%
2100	120	473.6	200.0	253.5	2.11	48%
2600 FDD	140	0.0	150.5	150.5	1.08	24%
2600 TDD	40	0.0	15.0	15.0	0.38	8%
Total	520		618.8	991.9		
% of mobile service revenue				4.5%		

Source: Coleago, Celcom analysis

Exhibit 26 below shows what the annualised cost of spectrum may be once 700MHz, 2300MHz and 2600MHz are assigned as Spectrum Assignments with a licence term of 20 years. For 900, 1800, and 2100MHz spectrum the prices shown are as per the current situation. The licence fees for the other bands are Celcom's lower range proposal. This would increase the annualised cost of spectrum to RM 1,105 million, equivalent to approximately 5% of revenue compared to 4.5% today. This assumes a small growth mobile service revenue.

Exhibit 26: Annualised cost of spectrum – 2020 (RM million)

Band	MHz	PC	AFC	Annua-lised cost	Annua-lised cost / MHz	% of highest
850	10	0.0	18.8	18.8	1.88	42%
900	60	1,309.2	112.6	265.6	4.43	100%
1800	150	1,426.3	122.7	289.3	1.93	44%
2100	120	473.6	200.0	253.5	2.11	48%
2600 FDD	140	99.3	99.3	109.4	0.78	18%
2600 TDD	40	28.4	28.4	31.3	0.78	18%
700	90	589	29.5	89.5	0.99	22%
2300	90	315	15.8	47.8	0.53	12%
Total	700		627.0	1,105.2		
% of mobile service revenue				5%		

Source: Coleago, Celcom analysis

Exhibit 27 below shows what the annualised cost of spectrum may be in 2022 following the assignment of 3500MHz spectrum and 26GHz spectrum (mm wave). This assumes that the 3500MHz spectrum be priced considerably lower than 2300MHz spectrum and the price for 26GHz spectrum would be even lower. Under this scenario the annualised cost of spectrum would be RM 1,147 million, equivalent to 5% of revenue, the same as in 2020. This assumes further growth mobile service revenue.

Exhibit 27: Annualised cost of spectrum – 2022 (RM million)

Band	MHz	PC	AFC	Annua-lised cost	Annua-lised cost / MHz	% of highest
850	10	0.0	18.8	18.8	1.88	42%
900	60	1,309.2	112.6	265.6	4.43	100%
1800	150	1,426.3	122.7	289.3	1.93	44%
2100	120	473.6	200.0	253.5	2.11	48%
2600 FDD	140	99.3	99.3	109.4	0.78	18%
2600 TDD	40	28.4	28.4	31.3	0.78	18%
700	90	589	29.5	89.5	0.99	22%
2300	90	315	15.8	47.8	0.53	12%
3500	300	95	4.7	14.4	0.05	1%
26000	1,000	32	1.6	4.8	0.00	0%
Total	2,000		641.0	1,147.7		
% of mobile industry revenue				5%		

Source: Coleago, Celcom analysis

Our recommendations for setting spectrum prices are informed by a forward looking approach that takes account of spectrum assignments to 2022 and ensures that the annualised cost of spectrum remains sustainable. [redacted] shows the evolution of mobile market revenue per MHz of spectrum assigned to mobile.

- We have assumed that in 2020, 90MHz of 700MHz will be assigned to mobile as well as 90 MHz of 2300MHz spectrum. This increases the amount of spectrum assigned to mobile from 520 MHz today to 700MHz by the end of 2020, an increase of 35%. However, mobile operator revenue is unlikely to increase by more much. This means mobile operator revenue per MHz of spectrum declines sharply as shown in the chart.
- We assume that 300MHz of 3500MHz spectrum will be assigned in 2021 and 1,000MHz of mm wave spectrum in 2022, further reducing the revenue mobile operators generate per MHz of spectrum used.

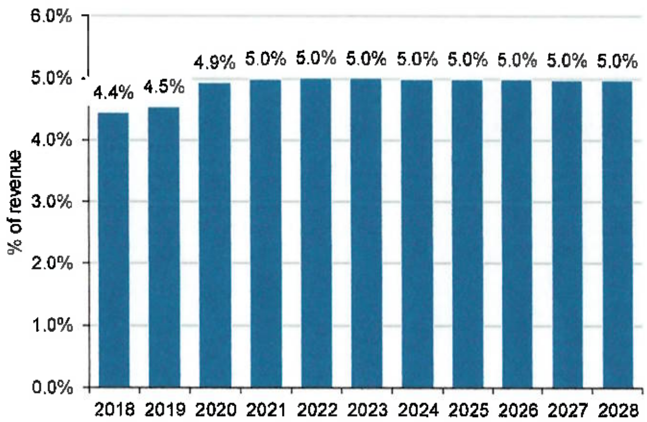
[redacted]

[redacted]

[redacted]

Assuming Celcom's recommendations for spectrum pricing at the lower end of the range are adopted, the annualised cost of spectrum as a percentage of mobile operator revenue will increase substantially in 2020 before stabilising. Under this scenario the annualised cost of spectrum would jump from currently 4.5% of revenue to 5.0%. Celcom considers this to be sustainable spectrum pricing in Malaysia in the context of achieving the goals of the NFCP and commercial launch of 5G in 2021.

Exhibit 29: Annualised cost of spectrum as a % of revenue



Source: Coleago

7.4 Discussion and evidence

7.4.1 The trade-off between licence fees and socio-economic outcomes

7.4.1.1 The 'Sunk Costs' myth

It is sometimes argued that lump-sum fees charged for spectrum licences do not bear on subsequent management decisions, because these fees effectively become "Sunk Costs". According to the theory, a corporation seeks only to maximise its future returns, and costs incurred in the past do not alter its optimal, forward-looking strategy.

If this Sunk Cost hypothesis was true, then short of bankrupting the industry, regulators could charge as much as they wished to renew licences, with little or no effect on retail market outcomes. From a policy perspective, this would represent a 'free lunch', in which the state could extract maximum licence payments from the industry while maintaining all of the welfare benefits generated by the industry's activities.

Consider, first, the experimental evidence (empirical evidence against the Sunk Costs hypothesis is presented in Section 7.4.1.2 below): Laboratory research carried out by Offerman and Potters in 2006 examined whether subjects' pricing decisions in competitive games were influenced by prior auction or fixed licence payments[15]. Their report concludes:

"Both in the Fixed Cost and the Auction treatment players charged significantly higher prices than in the Baseline treatment. In the long term, when the entry licences had been re-allocated a couple of times, the difference in average price levels between the treatments tended to become smaller. Nevertheless, even in the longer term, we found a significant positive correlation between entry fees and prices."[16]

These results clearly indicate that rational individuals take historical payments into account in their strategies, and with good reason: sunk costs are not simply forgotten.

Licence costs are carried forward for many years in the balance sheet. If these are funded through debt, the increased leverage may result in reduced credit quality, leading to higher costs of capital.

Because large upfront licence fee payments increase the operators' capital at risk, both willingness and ability to take risk tends to drop. More conservative strategies across operators are logical responses to heightened investor risk-aversion. These may result in higher retail prices and/or reduced investment. In the mobile sector, higher tariffs could typically result from slower price erosion.

7.4.1.2 International evidence on the welfare impact of licence fees

The conclusion that high licence fees lead to inferior mobile market outcomes is supported by credible sources and by empirical evidence from a broad range of markets. International research by NERA Economic Consulting for the GSMA indicates an empirical link between licence costs and retail prices, and an inverse relationship between licence costs and mobile industry output[17]. NERA observes that:

15 'Does Auctioning of Entry Licences Induce Collusion? An Experimental Study', T. Offermann and J.Potters, 2006, Review of Economic Studies, 73(3), 769- 791. The experiment involved a total of 166 students (presumably, drawn largely from the Tilburg University School of Economics and Management). These subjects were likely in a position to make rational decisions affecting their own payoff, which averaged €19.8 per participant (a significant sum for students at the time, for the limited time involved).

16 The 'Baseline treatment' alluded to in this report relates to instances of the game in which participants do not pay an upfront fee to trade.

17 See NERA, 2017: 'Effective Spectrum Pricing: Supporting better quality and more affordable mobile services', R,Marsden, B.Soria and H-M.Ihle.

"...where governments adopt policies that extract excessive financial value from the mobile sector in the form of high fees for spectrum, a significant share of this burden is passed onto customers through higher prices for mobile and lower quality data services."

NERA's quantitative findings are summarised in Section 7.4.1.5. We find support for NERA's conclusions from several credible sources, as discussed below. In the following, we also focus on direct evidence from a range of markets.

7.4.1.3 European Commission view on licence fees and 4G availability

The European Commission underscores NERA's concerns about the impact of fees on investment in the context of 4G:

"...there is [...] evidence that high [licence] prices can be associated with lower 4G availability."[18]

A lack of 4G availability is a symptom of underinvestment, and what is true for 4G must undoubtedly hold for other mobile technologies as well.

The view is based on empirical evidence from studies in European Union countries. Offermann and Potters offer historical evidence of a positive relation between licence fees paid by mobile operators and mobile retail prices, based on 1999 price data from the European Union[19]:

"Within the European Union the highest licence fees (more than 200 million Euro for the most valuable licences) have been paid in Austria, Belgium, the Netherlands, and Ireland, and the lowest fees (less than 5 million Euro) in Denmark, Finland, Luxembourg, and Portugal. Annual tariffs for a representative basket of services average about 750 Euro in the former four countries, but only 550 Euro in the latter four countries."[20]

Differences in levels of competition may blur comparisons. However:

"Ireland and Luxembourg are two countries with only two mobile operators. The most expensive licence in Ireland was 216 million Euro and average annual tariffs are about 1300 Euro. Luxembourg had licence fees less than 4 million Euro and annual tariffs of about 700 Euro."[21]

In this specific example, the price of the mobile consumption basket in the high licence-fee market was almost twice as high as that in the country with the lower licence fee. Such a high differential cannot be ascribed to differences in population density. For example, the population density in Belgium (a high tariff country at the time) is almost 70x higher than that in Finland (a low tariff country). It is also worth noting that Belgium had three mobile network operators in 1999, while Finland's third operator only launched in 2000.

18 European Commission News Article, 23 October 2017 (*ibid*).
19 T. Offermann and J.Potters, 2006, *ibid*
20 Offermann and Potters quote the following original source: European Commission, 'Fees for Licensing Telecommunications Services and Networks', Second Interim Report, European Telecommunications Office (ETO), July 1999.
21 Offermann and Potters quote the following original source: European Commission, 'Fifth Report on the Implementation of the Telecommunications Regulatory Package', COM(1999)537-final (Luxembourg: Office for Official Publications of the European Communities).

7.4.1.4 Evidence from the United States

Public policy towards the mobile sector should be focused on maximising social efficiency rather than on financing the state. This view is shared by Professors Thomas W. Hazlett and Roberto Munoz in particular, who argue that:

"...to maximise consumer welfare, [telecoms policy] should avoid being distracted by side issues like government licence revenues."[22]

Their main point is that the wider economic value (in terms of Consumer Surplus[23]) generated by the mobile industry far outstrips direct spectrum proceeds, and that measures that jeopardise the former in favour of the latter tend therefore to be "penny wise and pound foolish". According to their analysis:

"...the ratio of social gains [is of] the order of 240-to-1 in favour of services over licence revenues."[24]

On this basis, they conclude:

"A policy that has an enormous impact in increasing license revenues need impose only tiny proportional costs in output markets to undermine its social utility. So, for example, a new auction design that (heroically) doubled auction revenues would, if it reduced consumer surplus by just one-half of one percent, produce costs in excess of benefits".

7.4.1.5 Quantitative cross-country research

Based on their econometric demand modelling, NERA shows that reductions in licence fees would be more than offset by increases in Consumer Surplus[25]. The ratio of increases in welfare (in Consumer Surplus terms) to decreases in licence fees for 15 markets in their dataset is shown in Exhibit 30 below. These were markets in which licence fees exceeded the global median on a population and purchasing power parity (PPP) adjusted basis, and the calculations assume that licence fees are reduced to the global median.

On aggregate, NERA finds that the governments in these markets could have generated incremental value for society with a purchasing power of US$250 billion, had they surrendered as little US$98 billion in direct licence-fee receipts (on a PPP-adjusted basis)[26].

While the weighted average ratio of gains to foregone licence fees in this sample was 2.5-to-1, the median was 3.4-to-1 and the lowest (India) was 1.5-to-1, implying gains at least 50% higher than the foregone direct fee income for the State.

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22 Thomas W Hazlett, Roberto E. Muñoz, "What really matters in spectrum allocation design", Northwestern Journal of Technology and Intellectual Property, Winter 2012. Professor Hazlett served as Chief Economist of the US Federal Communications Commission. While their study was directed at spectrum allocation policy, their findings relate directly to licence fees.

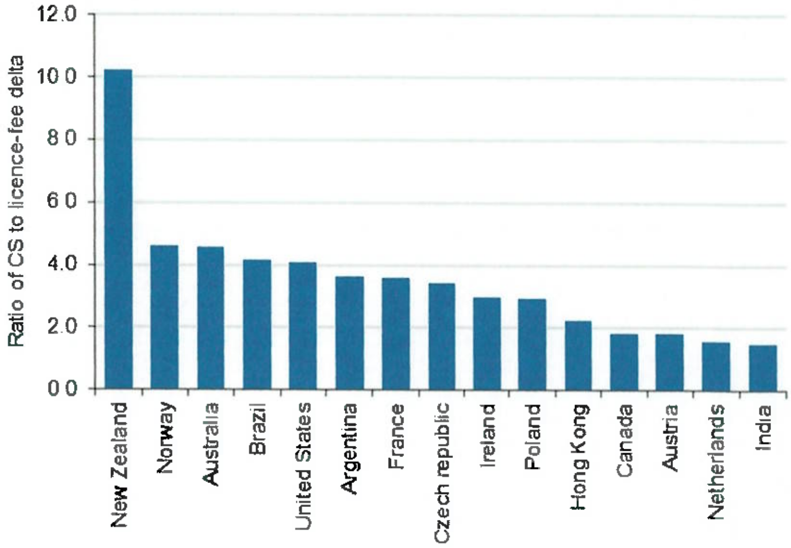
23 Consumer Surplus is the difference between the price consumers would be willing to pay for certain goods or services and the price actually paid. It is a key measure of economic welfare.

24 Using market data in the United States between 1991 and 2008, Hazlett *et al* obtained a lower-bound estimate for the 2009 Consumer Surplus in the order of $200 billion per year, or $4,000 billion in present-value terms (using a 5% discount rate). This is 80x greater than the roughly $50 billion raised by the FCC on a cumulative basis through spectrum auctions by 2008. They argue further that in order to compare efficiency gains, the social savings implied by auction receipts need to be considered rather than the pure transfers. In other words, the avoided deadweight losses that would have been incurred by using alternative means of revenue-generation should be taken as a basis. Assuming deadweight losses of 33%, the $50 billion raised /by the FCC corresponds with social savings of around $17 billion. This yields a ratio of about 240x in favour of retail market efficiencies.

25 NERA, 2017 *ibid.*

26 The average ratio of gains to foregone licence fees is 2.6x. The US$250 billion gain quoted by NERA thus corresponds with a reduction of 250/2.6 =US$98 billion.

Exhibit 30: Ratio of increases in welfare to reductions in licence fees



Source: NERA, 2017

By extension, we may conclude that the net (absolute) welfare gains would have been even higher if licence payments were kept below global median prices.

Finally, if reducing licence fees boosts welfare, then it follows that increasing them will diminish welfare. We may reasonably assume that over time, the ratio of welfare losses to increases in licence fees will be similar to the ratio of welfare gains to decreases in licence fees.

7.4.1.6 Further impact of licence fees on the national interests

In addition to the consumer welfare benefits, mobile communications have a strong indirect impact on productivity, GDP growth and national tax receipts.

Information lubricates the wheels of the economy. Mobile data allows individuals to stay informed wherever they are, and to share data files instantly, promoting widespread information and knowledge transfer. This too, drives efficiency and productivity. Mobile increases participation in the knowledge economy and helps bridge the 'digital divide': for many, mobile represents the sole mode of access to the Internet.

There are very few parts of the economy that are not touched by mobile communications. Due to these strong positive externalities, mobile communications are a critical industry for Malaysia and indeed for any country. These benefits increase with the widespread adoption and consumption of mobile services.

Several econometric studies have sought to quantify the positive effects of higher mobile data consumption on GDP growth.

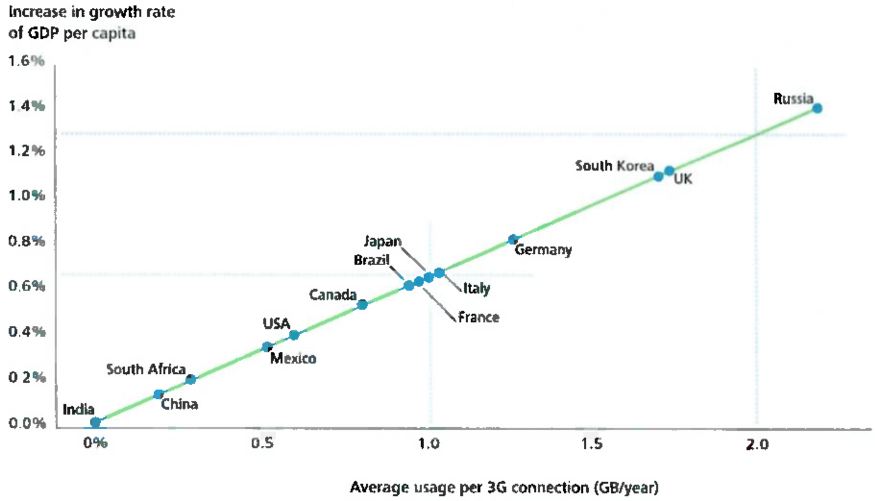
- An econometric study by Deloitte[27], using data from 96 markets between 2008 and 2011, found that a 10 percentage point increase in 3G penetration was associated with a 0.15 percentage point increase in GDP.
- Deloitte's study also found a strong relationship between mobile data usage and GDP growth. For a market with average data usage of 1GB/month per 3G connection, Deloitte estimate that over 0.6 percentage points of the growth in GDP

27 Deloitte LLP, 'The Economic Impact of Next-Generation Mobile Services: How 3G Connections and the Use of Mobile Data Impact GDP Growth', Chapter 1.6 in 'The Global Information Technology Report 2013', World Economic Forum.

per capita could be attributed to mobile data consumption. A doubling of average data usage would correspond with a doubling of the GDP growth attributed to 3G, as shown in the graph below.

The Deloitte study was made against the background of the introduction of 3G, but the underlying findings are not 3G specific. 4G and 5G are an evolution of the data capabilities of 3G to true mobile broadband in form of 4G with even higher data usage. With 5G we will see Gbps speeds and an acceleration in the growth of mobile data usage.

Exhibit 31: The effect of doubling mobile data usage per 3G connection



Source: Deloitte, 2013

From the evidence presented in Section 7.4.1.2, we can conclude that higher mobile licence fees result in higher retail prices and/or reduced investment in mobile infrastructure and services. Both of these would have a negative impact on the adoption of mobile and mobile data, as well as on data consumption per data user. This, in turn, would reduce GDP growth, leading to unrecoverable GDP losses.

7.4.2 The business case for 5G

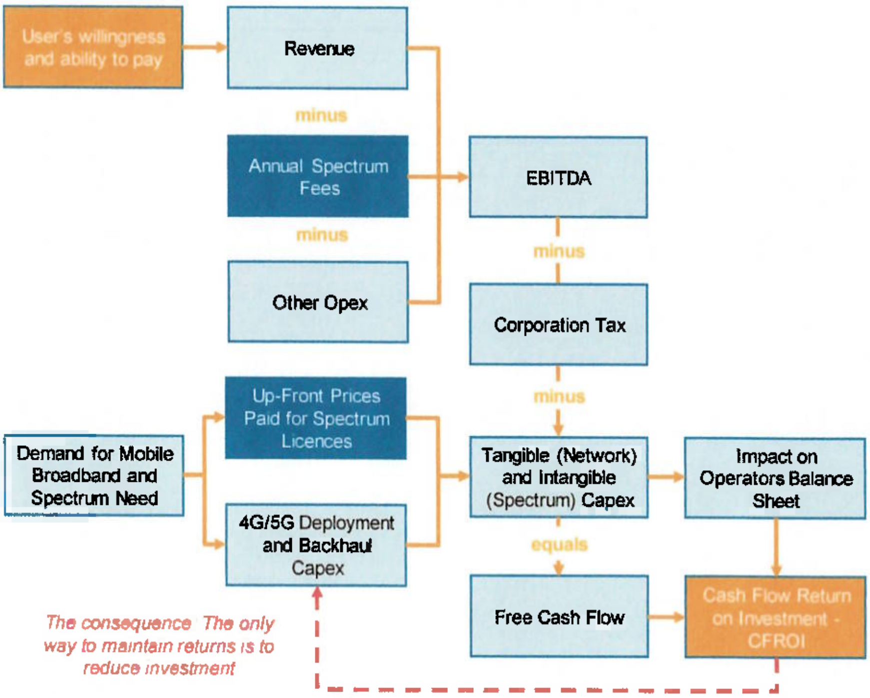
7.4.2.1 The trade-off between network investment and paying for spectrum

Let's look at the business case for investment in a mobile business. Exhibit 32 below illustrates the way cash flows through a mobile operator business.

- The mobile operator business case, like any business case, starts with revenue. Revenue is the limiting factor, because it is linked to customers' willingness and ability to pay for mobile services.
- Out of revenue operators have to pay operational expenditure (OPEX) such as network running costs, staff costs, annual spectrum fees (if any) and other government fees. Revenue minus OPEX produces a measure of profit referred to as Earnings Before Interest, Depreciation and Amortisation (EBITDA). EBITDA is essentially the cash generated from operations, but before capital expenditure (CAPEX).
- CAPEX is the investment in physical assets such as radios and towers (tangible CAPEX) and also spectrum assets (intangible CAPEX). EBITDA minus CAPEX is the cash generated by the business (simple free cash flow).
- Operators also pay corporation tax, i.e. there is a further cash outflow.

- Revenue minus operational expenditure, minus corporation tax, and minus capital expenditure is a measure of cash generated by a business, also referred to as free cash flow[28]. From this cash investors can be paid, i.e. lenders receive interest and shareholders receive dividends.

Exhibit 32: Spectrum licence fee impact on network investment



Source: Coleago

For investment to take place there must be a return on investment. Payments to lenders and shareholders represent the return on investment. If those returns fall to a level below that of investment opportunities with similar risks, it no longer makes sense to invest in the mobile business. Let's assume there is a large cash outflow to pay for a spectrum licence fee following a spectrum auction. Despite this, operators still need to generate cash to compensate investors or they would not be able to finance the investment in spectrum and network. The only lever operators have is to reduce tangible capital expenditure, i.e. invest less in the network to bring the overall capital expenditure to a level that can be financed. In short, if prices for spectrum for 4G and 5G are high, the 5G business case is unlikely to workable. Therefore a revenue extraction objective is not sustainable in the context of 5G.

The question of sustainable spectrum pricing is not theoretical. In some countries, due to excessive spectrum prices, the business case for further 4G related spectrum investment no longer makes sense. In India, Bangladesh, Ghana, Mozambique and several other countries spectrum pricing became unsustainable and held back the sale of 4G suitable spectrum and 4G deployment.

7.4.2.2 Investment in mobile broadband and 5G

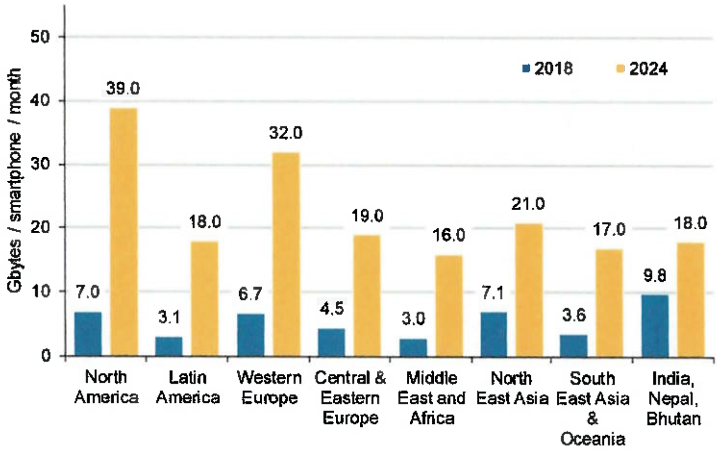
Mobile broadband traffic grew close to 88% between Q4 2017 and Q4 2018[29]. The trend points to an even steeper increase driven by the adoption of 4G and soon 5G smartphones as well as the increasing data usage per smartphone. Exhibit 33 shows the forecast average monthly traffic per smartphone between 2018 and 2024.

[28] Free cashflow also includes other adjustments such as changes in working capital but these are not material.
[29] Ericsson Mobility Report, Q4 2018

In 2018 Celcom's average smartphone customer used around [redacted] per month. As of July 2019, the average Celcom smartphone customer consumed [redacted] per month. This means Malaysians smartphone use is not only among the world's highest but also shows a large increase. Celcom and other mobile operators managed to cope with the traffic growth despite that fact that no new spectrum was assigned to mobile since December 2012.

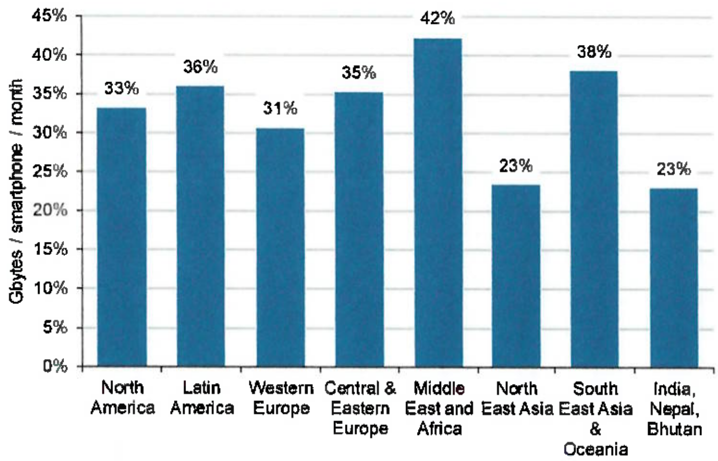
Depending on the country, monthly usage per smartphone will increase by 3 to 6 times, provided more spectrum and 5G is deployed. At the same time smartphone adoption will increase, particularly in emerging markets leading to large mobile broadband traffic increase in all mobile networks. Exhibit 34 shows a Compound Annual Growth Rate of 23 to 42% over the next 6 years. Malaysia will be no exception to this.

Exhibit 33: Monthly data traffic per smartphone



Source: Ericsson Mobility Report, June 2019

Exhibit 34: Mobile data traffic compound annual growth rate 2018-2024



Source: Ericsson Mobility Report, June 2019

To cater for this growth, operators are continuing to invest large sums in 4G and 5G radio access networks and backhaul infrastructure. Between 2018 and 2020 mobile network operators world-wide are investing US$ 480 billion in their 4G and 5G networks, i.e. around US$ 160 billion per year[30]. The vast majority of this investment is in the radio access network (RAN), notably cell sites, 4G / 5G radios, and backhaul. Investment in 5G is already under way, even in markets where the launch of 5G will take place a little later. Most 4G RAN investment currently taking place is software upgradable to 5G. Preparing for the launch of 5G, several operators started to deploy Massive MIMO in combination with three-carrier aggregation thus delivering Gbit/s speeds.

2019 saw the first launches of standards based 5G. However, the transition to 5G requires further significant infrastructure investment. Deutsche Telekom CEO Timotheus Hoettges estimated the cost of providing 5G networks in Europe at € 300-500 billion (US$487.2 - US$811.9 billion) and Sprint's CEO Marcelo Claure stated at this year's Mobile World Congress that in the US operators will invest US$275 billion in their networks. On top of the huge network capital expenditure operators need to acquire new spectrum below 1 GHz, in 2GHz to 4GHz and in mm wave bands.

A 5G mobile network is different from a traditional mobile network which has relatively large cell sites. A 5G network will have many more small cell sites because of 5G carried on higher frequencies. Estimates as to the number of 5G cells required vary greatly, but over the next ten years the number of outdoor cell sites in networks in advanced markets may increase by a factor of three - and more if indoor solutions are included.

The deployment of many thousands of 5G cells, for example on street furniture, requires an unprecedented investment in fibre and will push up network operating costs. A calculation by The Fiber Broadband Association of the US illustrates the size of the required investment: In an urban environment it will take eight miles of fibre cable per square mile to connect small cells. The largest 25 metro areas in the US cover 173,852 square miles which means that to provide 5G coverage will require around 1.4 million miles of fibre cable. Validating this analysis, Verizon stated in a press release in April 2017 that it will purchase from Corning up to 20 million kilometres (12.4 million miles) of optical fibre each year from 2018 through 2020, with a minimum purchase commitment of $1.05 billion.

On the positive side, operators will find some savings as they move to virtualised networks and increase infrastructure sharing. However, operating a mobile network with a factor increase in the number of cell sites presents a network operating cost challenge

7.4.2.3 Flat revenues

The investment in the new technology comes at a stage of the mobile industry lifecycle when revenues are declining in many markets. In markets where there is revenue growth, this tends to be below inflation, i.e. revenue is declining, as evidenced by research from Bank of America Merrill Lynch: *Globally, average mobile service revenue contracted 1.0% from a year ago as Emerging Markets and Developed Markets service revenue both declined. Revenue in developed markets declined -1.3% overall, with Asia-Pacific down 1.9%, Developed EMEA down 1.9% and North America down 0.7%. Emerging markets service revenue declined 0.7% in 4Q18 vs. last year's growth of 3.1% with Emerging Asia declining 2.5%, Emerging EMEA growing +3.0%, and Latin America expanding +1.6%.*[31]. In some markets revenues declined substantially, driven by competition. India is an extreme example of this where revenues declined by 14% in 2017.

[30] The Mobile Economy in 2019, GSMA
[31] Bank of America Merrill Lynch, Global Wireless Matrix, 30 April 2019

Mobile service revenue in Malaysia grew by an estimated 3.6% in 2018. Inflation was around 1%, giving a real growth of 2.6%. While the growth figure is better compared to most other countries, 2.6% real growth is very small compared to the doubling in mobile data traffic between December 2017 and December 2018.

But are there additional revenues to be had from 5G mobile broadband? Mark Allera, CEO Consumer, BT Group commented in March 2018: "*We will have to assume that consumers and businesses will be prepared to pay a little bit more for faster, higher quality access to the internet ...... getting some sort premium out of 5G as we did for 4G.*" In other words there is little or no revenue upside from enhanced mobile broadband (eMBB) which will account for the vast majority of 5G traffic.

However, most operators did not gain additional revenue from 4G compared to 3G. For example, when Vodafone India launched 4G, customers with 4G devices and a 4G SIM received 2 GB of data for the same price that 3G customers pay for only 1 GB of data. Vodafone's revenue did not increase but as a result of Vodafone's investment in 4G customers see a 50% reduction in the price per GB of mobile data.

A similar trend can be observed for 5G vs. 4G tariff plans. The evidence available so far shows that some operators attempted to launch 5G at premium price, but quickly abandoned this. Prices for 5G packages are not only not higher than for 4G, but also offer larger data volumes and of course high download speeds. In April 2019, mobile operators in Korea announced tariffs for 5G mobile. Depending on the tariff plan, in some instances 5G plans are cheaper than 4G plans. In early 2019 AT&T in the USA announced a 5G plan at rate of US$ 4.67 per GB compared to US$ 5 per GB for 4G.

Exhibit 35: 5G vs. 4G data pricing in Korea

	Package Type	5G			4G		
		Tariff KRW	Data pack	Limit after out of pack	Tariff KRW	Data pack	Limit after out of pack
LGU+	Entrance	55,000	9GB	1Mbps	55,900	6.6GB	3Mbps
	Middle	75,000	150GB	5Mbps	74,800	16GB	3Mbps
	High	85,000	Unlimited	Unlimited	88,000	30GB	3Mbps
	Premium	95,000	Unlimited	Unlimited	110,000	40GB	3Mbps
SKT	Entrance	55,000	8GB	1Mbps	50,000	4GB	5Mbps
	Middle	75,000	150GB	5Mbps	69,000	100GB	5Mbps
	High	95,000	Unlimited	Unlimited	79,000	150GB	5Mbps
	Premium	125,000	Unlimited	Unlimited	100,000	Unlimit.	n/a
KT	Entrance	55,000	8GB	1Mbps	49,000	3GB	1Mbps
	Middle	80,000	Unlimited	Unlimited	69,000	100GB	5Mbps
	High	100,000	Unlimited	Unlimited	89,900	Unlimit.	5Mbps
	Premium	130,000	Unlimited	Unlimited	n/a	n/a	n/a

Source: Operator websites

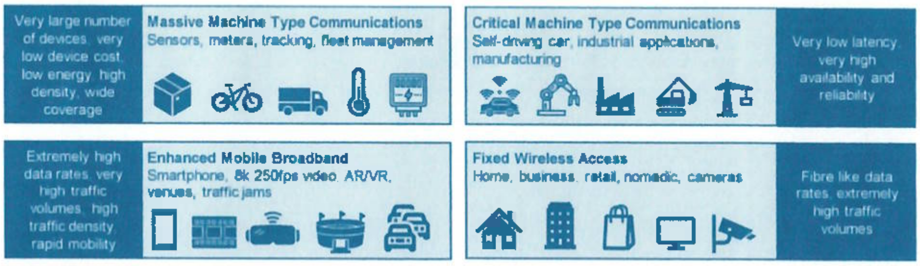
The IoT market is projected to grow significantly, but more than 80% of the IoT market are services other than connectivity. These services, which by and large are not provided by mobile operators, include applications, platforms and services such as cloud data analytics and security, as well as professional services such as systems integration, consulting and managed services. Connectivity, i.e. mobile data, accounts for only a small part of the IoT revenue stack.

While the IoT market is promising, connectivity revenue may only add around 5% to revenue. This view is supported by the excellent statistics gathered by the French regulator shows that in 2011 IoT (M2M) SIMs accounted for 4.9% of all SIMs and 0.4% of revenue. By the end of 2018 IoT SIMs had grown to 19.5% of all SIMs but IoT revenue was a tiny 1% of total mobile service revenue. Furthermore, this small revenue slice also has to pay for investment in IoT optimised networks such as LTE-M and NB-IoT. Because future cash flows from IoT will be small, they cannot support the business case for high spectrum fees.

Of course 5G is a technology platform which opens up opportunities beyond enhanced mobile broadband, including serving the so called "verticals", smart cities, autonomous vehicles and robotics. Connectivity is the glue of the 4th industrial revolution. The amount of data generated by millions of sensors and other devices opens up opportunities in the application of AI services. However, this is where the business case becomes rather uncertain and mobile operators are unlikely to be the main beneficiaries from this. Big investment bets, including investment in spectrum, will not be driven by business cases with a highly uncertain revenue potential.

The evidence is clear: With no growth in revenue, continuing high levels of capital expenditure and growing network operation expenditure the business case for 5G is finely balanced. For operators the introduction of 5G is not primarily about new revenue but it is necessary to bring down the cost per bit, given the massive growth in data traffic.

Exhibit 36: 5G use cases



Source: ITU, Huawei, Ericsson, Coleago

7.4.3 Sustainable level of spectrum pricing

7.4.3.1 Mobile operator revenue per MHz of spectrum is declining

Some regulators believe that more spectrum results in increased revenue. While this was true during the growth stage of the mobile industry life cycle, it is no longer the case. In most markets around the world, revenue generated per MHz of spectrum deployed has declined over the period 2007 to 2019. For example:

- In Canada mobile market revenue per MHz declined from CN$81 million in 2007 to CN$33 million in 2019 – a 60% decline.
- In France over the same period revenue per MHz dropped from €52 million to €21 million – a 59% decline.
- In Germany between 2007 and 2018 revenue per MHz declined from €63 million to €25 million, a 60% decrease. Once the c-band spectrum auction currently under way concludes, revenue per MHz of spectrum will be down to €17 million, bringing the 2007-2019 decline to a steep 72%.
- In Singapore mobile market revenue per MHz declined from SG$9.4 million in 2007 to SG$4.5 million in 2019 – a 52% decline.
- In Malaysia revenue per MHz in 2018 is actually 4% above the 2007 figure. This is due to the fact that so far in Malaysia only 610 MHz of spectrum is assigned to

mobile compared to 657 MHz in Canada, 600 MHz in France, 1000 MHz in Germany, and 649 MHz in Singapore.

The evidence is clear: Incremental spectrum does not generate incremental revenue. However, additional spectrum can produce some cost savings, however the effect is relatively small because mobile data traffic increases rapidly. Savings as a result of having access to more spectrum are offset by investment to deploy additional radios and backhaul capacity.

[redacted]

As explained above, mobile operators will use several times more spectrum in the transition to 5G than they currently use to cope with the increase in data traffic. The forthcoming spectrum assignment in Malaysia adds new spectrum to mobile, namely the 700MHz band and the 2300MHz band. WRC allocation for spectrum for mobile use include many more bands. For example, in the C-Band (3.3 – 3.8GHz) most countries have or will assign approximately 400MHz. On top of the C-Band other spectrum may be added, for example 1500MHz and later on mm wave spectrum, i.e. 26GHz and above. Depending on where countries are on their spectrum roadmaps this will double the amount of spectrum deployed by mobile operators.

The ITU's 5G design calls for the ability to serve 10 Mbit/s per square meter. The combination of 5G New Radio and additional spectrum will make it possible to serve high traffic densities in urban areas. Indeed, the 5G business case is mainly about catering for high traffic densities rather than any new revenue streams or a new business model.

As explained above, given that revenue will increase only very slightly or not at all, revenue per MHz of spectrum deployed will decline substantially during the next few years. Therefore in economic terms, the deployment new spectrum for 5G does not deliver a producer surplus but instead it delivers a significant consumer surplus. The consumer surplus arises because data volumes are increasing while users do not pay more. Therefore users get vastly better value for money in terms of the price paid per Gbyte of traffic. This is simply the continuation of a by now familiar trend in digital services and products to offer ever better capabilities while the cost of ownership to users does not increase.

Th economics are straightforward. New spectrum is not generating additional producer surplus and therefore it is not economically feasible to extract substantial incremental fees for the use of new spectrum.

7.4.3.2 Calculating the total cost of spectrum to operators

Depending on the country, the calculation of the annualised cost of spectrum can include one or two elements:

- An up-front spectrum licence fee for a 20 years licence which tends to be substantial. This is usually the outcome of a spectrum auction but in some cases is simply the same as the (rather high) spectrum auction reserve price. The annual equivalent cost of an up-front spectrum fee can be calculated using an annuity formula. The annuity formula takes account of the amortisation of the licence, i.e. it only lasts 20 years, and the cost of capital to finance the up-front spectrum fee.
- Some countries charge an annual spectrum licence fee instead of an up-front fee. For example, in the UK after the expiry of the initial licence term operators pay an annual fee set by the regulator. In the recent spectrum auction in Indonesia operators bid an annual fee instead of an up-front fee. In Mexico an annual spectrum fee is set by law with and an additional up-front fee is determined through an auction process.

The upfront fee paid for spectrum can be used in a standard annuity formula which translates the up-front fee into an equivalent annual cost of spectrum, i.e. the annualised cost of spectrum. Fees paid for spectrum in the past need to be financed by loans or by shareholders. Interest has to be paid on loans, i.e. this is a cost. Over the term of the licence, for example 20 years, the cost of the spectrum licence which sits on the operators' balance sheet is amortised, i.e. each year 1/20% is passed as a cost though the income statement. These two elements are used to convert an upfront annual fee into an annual equivalent, i.e. the annualised cost of spectrum.

As mentioned above, in some markets there are also annual spectrum fees. These fees need to be added to the annualised cost of upfront spectrum fees to obtain the total annual cost of spectrum. The total annual cost of spectrum can then be compared with the annual industry revenue.

The annualised cost of spectrum methodology provides a metric which allows regulators to compare the price of spectrum relative to the size of the mobile industry in their country. The key advantage of this approach is that it is forward looking rather than using benchmarks from past auctions or from other countries. Using the annualised cost of spectrum methodology, regulators can look at their spectrum assignment roadmap and assess what level of spectrum pricing would be sustainable in the context of the mobile industry in their market.

Exhibit 38: Annuity calculation formula

The annuity calculation formula to convert up-front spectrum fees into an annualised cost of spectrum
Annualised cost = Up-front spectrum fee x cost of capital / (1 - (1 / (1 + cost of capital)) ^ years of licence term) Note: The cost of capital is the weighted average cost of capital (WACC), a figure also used for regulatory cost accounting and hence available to regulators

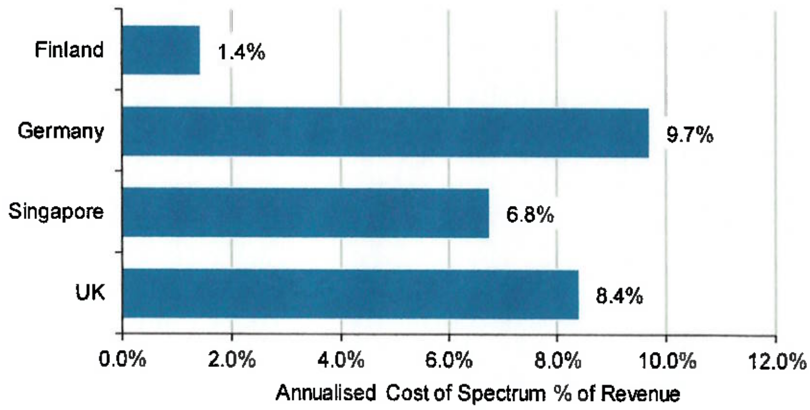
Source: Coleago

7.4.3.3 The annualised cost of spectrum in selected countries

Coleago has calculated the annualised cost of spectrum in a sample of countries as shown in Exhibit 39. Based on mobile industry service revenue the annualised cost of spectrum in Finland was 1.2%, in Germany 9.7% of revenue, in Singapore 6.8%, in the UK 8.4%, and in India 14.8%.

- A cost of spectrum of up to 5% is unlikely to slow down investment in mobile broadband and 5G. The evidence from Finland (see chapter 0) indicates that a lower percentage is likely to deliver better outcomes for 5G deployment.
- In many well developed 4G mobile broadband markets the annualised cost of spectrum is 5% of mobile operator service revenue but recent spectrum auctions pushed up the cost to as much as 9% as illustrated by the example from Singapore, Germany and the UK.

Exhibit 39: Annualised cost of spectrum % of revenue, selected countries



Source: Coleago

Good policy makers understand that the socio-economic benefit of mobile broadband is far greater than spectrum licence fee revenue could possibly generate.

- Finland has a clear policy of minimising spectrum fees instead seeks to incentivise operators to invest in the network. The annualised cost of spectrum in Finland is only 1.4% of mobile operator revenue. This has resulted in Finland being on top of the mobile broadband league table in terms of per SIM mobile date usage download speeds (see chapter 7.4.4 below).
- Germany and Singapore are well regulated telecoms markets with a high level of transparency and have very similar spectrum costs. Revenue maximisation from the sale of spectrum is not a policy objective.

7.4.4 Spectrum pricing to deliver policy objectives

7.4.4.1 The trade-off between spectrum fees and rural coverage in France

A key difference between countries is the cost of coverage. Covering a city, such as Singapore, is economically easy because every site has a high traffic utilisation, i.e. every site generates a return on investment. However, rural sites generate less revenue per site, and they are also more costly in terms of capex and opex. In rural areas, the cost of delivering services is 25% higher than in cities[32]. This means that operators do not achieve a return on investment on rural sites in Malaysia which needs to be considered when looking at relative levels of spectrum pricing.

[32] Opex per cell site is 25% higher in rural areas than cities – and 100% higher in remote areas (source: GSMAi: 'Unlocking rural coverage' report)

France provides a good illustration of how a change in government policy leads to very different prices being paid for spectrum before and after the change in policy. France used to pursue a policy of extracting revenue from the sale of spectrum licences. In the 700MHz auction in November 2015, the reserve price was 0.66 $/MHz/pop. This is very high compared to the 0.21 $/MHz/pop in Finland.

Due to the high cost of spectrum, French mobile operators held back investment in rural areas leading to poor mobile coverage and low mobile broadband speeds. This shortcoming had been identified as a factor holding back economic development in small towns and villages of France and the realisation led to a change in the Government's approach to spectrum pricing. When in 2018 the regulator renewed expiring spectrum licences in 900, 1800 and 2100MHz (licences expiring between 2021 and 2024), the Government decided not to auction the spectrum nor to charge a renewal fee. Instead the Government asked mobile operators to invest more in rural mobile broadband coverage. This change is policy was clearly stated by the regulator, AECEP, see Exhibit 40.

In terms of telecoms development objectives there are similarities between Malaysia and France.

Exhibit 40: Change in Government spectrum pricing policy in France

Implementing 4 new principles to generalize a good quality mobile coverage for all

1. **Change of paradigm for the State**	For the first time in a frequency allocation, the digital coverage of the territory takes precedence
2. **Operators' commitments for a gradual improvement of mobile coverage in the daily life of the people**	Generalization of 4G coverage, coverage of major roads, indoor coverage, no more obligation of coverage expressed in terms of a % of the population
3. **A solution for challenge areas**	Operators will use their own funds where the authorities have identified coverage needs
4. **Acceleration of digital coverage throughout the country**	The Government will implement measures to simplify deployments under the Housing Bill; other regulatory measures will follow.

Source: French perspective on spectrum issues, Spectrum 5.0 : New Directions in Spectrum Award for 5G, page 11, Pierre-Jean Benghozi, ARCEP, Paris, 5th of October 2018

7.4.4.2 Low spectrum fees and world-leading mobile broadband in Finland

Finland has consistently pursued a policy of low spectrum fees in order to enable operators to invest the maximum in their networks. The annualised cost of spectrum amounts to a mere 1.4% of mobile industry revenue. As a result mobile operators in Finland have built a very high density mobile network which delivers excellent availability and high download speeds.

Finland has the densest LTE cell site grids, but below average number of spectrum bands deployed per LTE site and outperforms most European countries in key LTE performance metrics – even in the most loaded hours of the day – despite having 8x the European average and 17x the German traffic load, normalised for population[33].

33 Rewheel-Tutela public research study, 18th February 2019

The benefit for users is clear: The average monthly mobile data usage per SIM in Finland is, at around 20 Gbytes, the highest in the world together with Kuwait and some other Gulf states. Three of the top four best performing mobile broadband networks are in Finland as shown in Exhibit 41 below.

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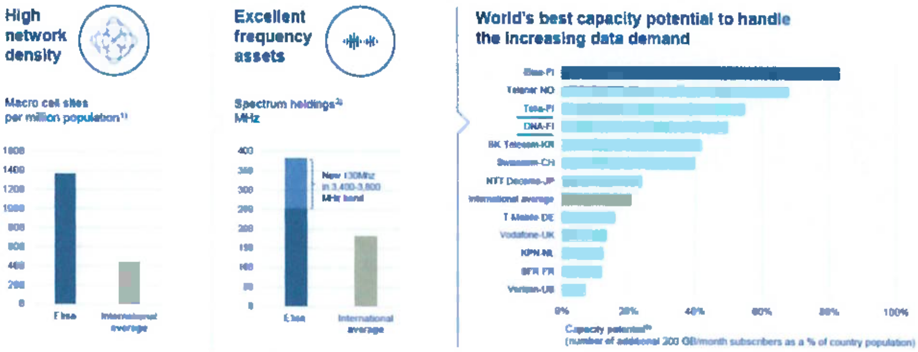
Exhibit 41: Finland leads in mobile broadband



Source: Elisa Capital Markets Day presentation, 2018

