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Digits to Dollars

D/D #25: I Got 99 5G Use Cases; and Consumer ain't One

We spent last week in Barcelona for Mobile World Congress where there was really only one topic – the upcoming roll-out of the 5G wireless standard. We can sum up all you need to know about 5G in one sentence:
The roll-out of 5G will like pretty much like the rollout of all the previous standards.
The rest is noise. But Oh My Goodness what incredible, juicy noise it is. Buckle up this is a wild ride.

The Case for 5G and the Use Case Mirage

In the span of any given 24 hour period at the Mobile World Congress (MWC) we could count on speaking to people who were 100% convinced (and convincing) that the 5G roll-out is both big and imminent AND to also speaking to people who were equally convinced (and convincing) that 5G is over-hyped boring-ware. The fact that these two people would often cite the other as evidence of their argument just added to the fun. For all the "Smart Toothbrush" hype, we still have a lot to work out in 5G.

How 5G Plays out for the Supply Chain

One clear theme of the show was that everyone seemed to be in a really good mood. Maybe it was the weather. Or maybe it is the fact that MWC is a show for suppliers selling things to Telecom Operators, and the operators are buying things. Or at least the suppliers think the Operators have a good reason to be buying thing. We try to identify a few winners and losers. Our focus is on handset modem vendors and the perennial question – What will Apple do for 5G?

Sympathy for the Operator

We spoke to many operators at the show and came away with the sense that their driving emotion right now is fear. They are feeling the pressure to deliver new business models largely centered on enterprise sales of 5G networks. We think it will be challenging for the operators to build the partner ecosystems needed to accomplish this.

Executive Summary

A lot happened at Mobile World Congress this year, and we wanted to back up our findings as much as possible, so this is a long note. As a helpful summary, below is a quick list of highlights, with more complete write-ups in the following pages.

- Many, many people told us some version of "Carriers only make money on even-numbered G's." One carrier actually put that in a slide they were showing vendors. Despite all the hype of 5G, there is a distinct lack of operator enthusiasm because of this.
- Several people told us Huawei's Balong is the best 5G baseband on the market right now. Qualcomm has a new product coming, but it is significant that an in-house modem has the lead.
- 5G has little benefit for consumers. Mobile data rates will gradually improve, but most people already take that as a given. The exception to this is China where plans for 5G are advanced, pushed by government initiatives, could propel the network for an early version of 4G to 5G quickly. As a result, there could be a consumer-noticeable improvement in mobile data rates.
- The really big speed boost from 5G only come with the second part of the standard with the use of millimeter wave frequencies. But these have much shorter range and will require mass deployments of small cells. No one knows who is going to pay for these or even where they can be installed.
- Operators are searching for viable 5G use cases, mostly focused on enterprise and IoT (Internet of Things). Whether they can find these and how they will actually deliver them are important open questions. As one person told us the carriers are still searching for their minimum viable product (MVP).
- Even the most advanced telecom operators are increasingly relying on public cloud infrastructure. One contact told us that both AT&T and Verizon are each already spending $1 billion a year on AWS.

- Apple does not have any good options for obtaining a 5G modem any time soon. There is a real possibility of no 5G iPhone until 2021. This may not matter to many consumers, but it will probably matter a lot in China.
- We asked some engineers from a major equipment vendor demo-ing 5G network capacity “How much does 5G improve spectral efficiency?”. They responded “You have to ask our marketing people.” When you dig into the improvements of 5G, you will find that much of the gains in bandwidth come from using new spectrum.
- Ericsson’s and Nokia’s 5G products may not be ready for full scale deployment yet. One contact estimated that Huawei was a year ahead.
- The move towards labelling everything as “Smart” continues unabated – Smart 5G Air Taxis (aka helicopters), Smart Cars, Smart Bulldozers, and at MWC even Smart Toilets and Smart Toothbrushes.

The State of 5G

The big question to answer at MWC this year was the state of the 5G standard. There is an awful lot resting on this topic. There are many (!) of ways to view the current state of the standard right now, but a few things are very clear.

As we stated at the top of this note, the sober view is that the new standard will roll out pretty much just as all the standards do. Deployments start this year, over the next seven or eight years, the bulk of mobile subscribers will gradually move onto phones using the new standard. Mobile data rates will steadily improve. Your phone bill continue to go up. (Can you remember the last time it went down?) Some countries will move faster than others to 5G. Some companies will miss a product cycle and sink beneath the waves. Others will prosper on some combination of good execution and luck.

If you are not in the mobile industry, you can probably stop reading now. You will miss the fun in the details, but this is the hard reality.

However, if you are still reading this, we will start peeling away the layers and dig into the very messy internal dynamics of the mobile industry.

A Standards Primer

As always, we like to start with some background. 5G is the Fifth Generation of the mobile standard, which is officially known as 3GPP. That standard has been around for 20+ years, and has steadily delivered improvements in call quality and data rates. Never forget that it is a small miracle that we can all stand almost anywhere in the world and call someone anywhere else in the world, while playing a 3D game on that same “phone”.

This is possible because years ago all the mobile operators agreed to standardize the way that mobile phones communicate with the rest of the phone network and then later with the broader Internet. This common set of communication protocols and radio signaling is incredibly complicated and esoteric, but it works.

Each of the past generations has offered a major change in the way that the network handles these communications. The major difference in each generation rests in the portion of the standard that handles the way a mobile phone connects to the base station, or antenna. Since this is the truly wireless part of the standard we call this portion the ‘air

interface', it handles how radio signals transmit data over the air. Every subsequent generation has introduced improvements to the air interface. All this talk of 'G's really boils down to finding new ways to squeeze more capacity out of the radio spectrum. The advent of 2G brought the air interface from an analog signal to a digital signal which meant we could apply computers to the signals. 3G introduced CDMA-based protocols (don't worry about what the acronyms spell out, it does not make things any clearer). 4G introduced OFDMA. Again, these are just new ways to manipulate the radio spectrum.

But then we ran into a little problem. Over the years, we have pretty much run out of fundamental ways to manipulate the air interface. Radio signals are now modulated by frequency, phase, amplitude, tone, time and space. There are no more fundamental levers to pull. Unlike all the prior standards, 5G does not have a single 'tentpole' being used to squeeze out more capacity from the radio spectrum. Instead it is 1,000 small tweaks. There are still lots of ways to improve mobile capabilities, but there are no more single big gains.

For consumers the progression of standards has meant faster data rates. However, for the operators the real significance of the standards is the improved 'spectral efficiency' they provide. The most important asset the carriers own is their radio spectrum, the portions of the radio channels they are allocated for deploying their systems. The more efficient the spectrum the more use they get out of it. This is by far the biggest driver of the advance of the standards.

Every new standard has a few component steps. First the standards body needs to finalize the specifications. Then the base station vendors need to have equipment for the network, and the handset makers need to have new devices which require a bunch of new chips. The introductions of every standard has had to undergo a bit of a rough patch in this regard, with one constituency lagging behind the others in early days, until eventually everything gets sorted out. This time will be no different.

Which Brings us to 5G

To understand the current state of 5G, we need to look across a number of different disciplines, each of which comes from separate multi-billion dollar industries. To further complicate things, we also need to break the standard into manageable pieces. There are a lot of requirements for complying with the 5G standard.

The components of the system are:

- Spectrum – do the carriers own the radio channels they need?
- RF Semis – The analog chips in phone which sit next to the antenna and process electric signals and convert them into 1's and 0s
- Modems – These are the digital processors in a phone which decode the bits coming from the radio
- Handsets – Devices, especially smart phones
- RAN – The Radio Access Network, the base stations which are the first point of contact for signals from the phones

As we have been repeating, the 5G standard introduces a large number of small changes. To greatly simplify matters, we want to break this down into three buckets:

- The air interface in traditional spectrum – we will refer to this as "Sub-6" (as in radio frequencies below 6 GHz)
- The air interface in new spectrum bands – we will refer to this as millimeter wave or mm wave
- Changes to the core, wired telecom networks.

We have labeled these as 'small' changes, which we mean that in the sense that each of these has a small contribution to the overall network improvement, but each of these means big changes for the equipment required.

Let's walk through each of the new areas of changes.

Sub 6 -The new, sub-6 air interface requires new basebands for phones. These are ready now with Qualcomm now sampling its second generation of chips, and internally-produced versions from Samsung (Exynos) and Huawei (HiSilicon) ready(ish) as well. Mediatek, which typically lags new standards will have chips this year, a noticeable

improvement for them. Intel is behind here, and you bet we will come back to that. Phones also need RF chips (from companies like Skyworks and Qorvo), but for Sub-6 5G the RF components required are pretty similar to what we are using in already in 4G. On the base station front, to really take advantage of some important new features in 5G (aka beam forming), the operators will need to add some new equipment to their base station antennas (e.g. beam forming arrays). The standard will work without them, but it definitely works better with them, so expect the carriers to deploy them gradually over a few years.

Core Network – One of the biggest changes in 5G are new features to operate inside the carriers' wired networks. Everything from the base station to the Internet. To greatly simplify this, the new standard moves the carrier networks towards a more flexible architecture that looks a lot more like the Internet than the traditional special-built telco networks of the past. It is always hard to quantify the progress the operators make on this front. It is not a simple matter of adding one more box. In many cases, the operators will need to do a complete overhaul of their core networks, and this will take a long time. Our guess is that almost no one is ready for this right now, but many carriers have been steadily chipping away at it for years. In theory, this should allow them to meaningfully reduce their operating costs. In practice, we expect it will be a few years before any external observers will be able to detect any differences here.

mm-Wave - The last bit of changes involve introducing a whole new set of radio frequencies. These are higher frequencies well above where the mobile networks have traditionally operated. They are interesting because they offer some very big improvements in speed, but these come at the expense of much shorter range. Here is where everyone gets a bit more speculative. We will delve into this in greater detail later, there are still a lot of questions marks and TBD labels here.

A crucial problem with mm-Wave is that radio signals in these bands do not travel as far as in traditional bands. Range here is measured in hundreds or even tens of meters as opposed to kilometers for 4G signals. This means for 5G mm-Wave to work, operators will need to deploy many small cells. This will not be easy. First, finding suitable sites will be

expensive. Second, cities everywhere are already pushing back on towers and telco boxes, even small ones. Third, installation is labor- and time-intensive. Fourth, connecting these devices back to the core network (aka backhaul) is not easy and requires a lot of permission to dig up streets or use unproven wireless techniques. At the show, we found no one wanted to discuss these topics. The irony is that small cells were once a very hot topic in 4G. We wrote a long piece about this for MWC 2016. It turned out that the industry was not able to pull it off then. Maybe the motivation is much stronger this time around, but it remains unclear how wide these deployments will be. Which then raises the question of what speeds we can really expect from 5G any time soon.

Readiness of the 5G constituencies					
	Spectrum	**RF**	**Modems**	**Handsets**	**RAN**
Sub-6	Partially available	Ready	Ready	20+ phones	In-Process
mm-Wave	Limited availability	Limited, early samples	Limited, One Supplier	5 phones	Limited
Core Network	na	na	na	na	Very early

The problem that everyone at MWC was solving for is "When will the carriers start deploying their 5G networks?" This is literally a $64 billion question. And at this point we start to encounter our first elements of cognitive dissonance.

If you read the public and press accounts of 5G, the operators are lock and loaded, ready to start deploying 5G right now. This was the clear marketing message at the show. The reality is much less confident.

In private conversations, it quickly becomes clear that the operators are very nervous about rolling out 5G. As should be clear from the above discussion, there is a lot of money at stake. We will walk through this economic analysis below. Our best guess is that the US carriers will start deploying this year as will the operators in China. Japan and South Korea

will start a bit later this year, or maybe next. Everyone else is in a wait-and-see holding pattern. And there seem to be lots of caveats and hedging about how extensive the deployments in China and the US will actually be.

A closing note about China. This could be one of the bright sparks of 5G deployments. The government there has made 5G deployments something of a policy priority. True to historical pattern, this policy is not 100% clear. Most people agree that the Chinese operators will begin deploying "100's of thousands" of 5G base stations this year. A big number but short of a nationwide network. And then there is the question of licensing. Typically, the operators do not get a license to turn on those networks for commercial purpose until they meet some (publicly) unspoken objective.

That being said, this is an important development. China's 4G networks today are widespread but they are not operating to the full extent of the standard. They have not added a full range of capacities to the network (e.g. carrier aggregation of RF bands). As a result, mobile bandwidth in China lags what we find in other markets. If the operators here jump to 5G quickly, this will likely bring about a big jump in the data rates that consumers enjoy. So while 5G will likely mean little to most consumers, in China there is a chance that it could be very noticeable to users, spurring greater demand for 5G phones.

5G – Is anyone On the (Use) Case?

As much as we can dive deep into the technical details of 5G, the real foundation of all of this is money. The operators will start spending on 5G when they believe they can generate a profit.

Profits, of course, have two components revenue and costs. The cost side of 5G is fairly clear. The new standard should allow for greater spectral efficiency which lets them get more usage out of their precious spectrum assets. The changes to the core network coming in 5G should also do a lot to help the carriers reduce the operating costs of running those networks.

However, here we encounter another wrinkle. While the marketing documents all proclaim 5G as reducing costs, when we started digging a bit deeper on these claims we found a surprising degree of uncertainty. At one point, we asked engineers from one of the leading equipment makers the simple question of "How much more spectral efficiency does 5G deliver?" their eyes immediately flashed panic, and they quickly responded "You need to ask our marketing people." Um… shouldn't that be the other way around?.

It is also important to keep in mind that the new standard is being rolled out in a number of new frequency bands. That means the carriers have to go out and purchase it from the regulators. One of the unspoken problems with 5G is that many of its gains come from using new frequency bands, not from greater spectral efficiency. There are efficiency gains, but that is only part of the way 5G delivers increased bandwidth.

Then we come to the question of increased revenue. If the cost reduction side of 5G is not quite so compelling, then the investment case needs to rest more heavily on revenue increases.

And now we come to the biggest problem of all. Today most mobile operators generate the majority of their revenue from consumers. And most of their enterprise revenue comes from bulk purchases of service for employees (i.e. consumers).

So will 5G lead to a spike in consumer mobile revenue? Simple answer to that – No. Why would consumers pay more? Maybe a big increase in speeds, but those are still years

away. For the foreseeable future 5G will lead to gradual not ground-shaking increases in speeds. And consumers are already accustomed to getting these.

We spoke with a senior executive at one of the equipment majors who flat out told us that “5G is not about the consumer”. And we so no reason to disagree with this.

Which all leads to the conclusion that the investment case for 5G rests largely on the carriers delivering new services that businesses will want beyond basic smartphone service.

This was evident at the show where every exhibiting operator and equipment provider filled their booth with 5G Use Cases. A dizzying array of science fiction future applications powered by the wireless network. We heard that one operator presented 600 use cases to their equipment providers last year.

During the show we tried to count use cases. Unfortunately, many of the use cases failed the very basic question of “Couldn’t we do that with 4G?” In all we found a few dozen use cases that could credibly claim to be both dependent on 5G and actually useful.

Many of the functional use cases for 5G revolve around high-density deployments – stadiums, million-drone swarms, etc. Here the increased bandwidth of 5G will allow for more simultaneous users.

Promoters of 5G hold up the standard as providing two major benefits – greater bandwidth and reduced latency (i.e. the delay in sending communications over the network). As we noted above, much of the growth in bandwidth comes from the use of new radio spectrum, which poses a much more challenging return on investment (ROI) calculation because spectrum is expensive.

The latency argument holds up a bit better, as 5G does show much less network delay. One operator was demonstrating surgery where a remote operator manipulated surgical tools controlled over a 4G network side by side with the same operations on a 5G network. It was very clear that the 5G-networked tools were much more responsive. This is all fine, but we will say right now that we will never willingly submit to wireless surgery in 5G or 6G or 10G. If someone were to operate on us, we really hope they would pay a little bit more and use the wired controllers which will always have less latency.

Our intent here is not to diminish the improvements of 5G. These networks will (eventually) be faster and provide less latency. However, the investment case is just not that clear cut. Most operators are going to take their time deploying the standard unless compelled by particular competitive dynamics (USA) or government imperatives (China).

And that is the optimistic case. When we spoke to people when their guards were down (1am at the Tapas bar, the two-hour customs line at Kennedy Airport, etc.) we heard a chilling refrain over and over again – "Only the even-numbered G's are profitable". 2G sparked massive consumer adoption. 3G was never really profitable, in part because of inflated spectrum prices. 4G was very profitable on the back of smartphone adoption, and fully depreciated spectrum purchases. As we head into 5G, we heard many operators privately admit that they do not expect to see 5G achieve profitability. And that carrier we mentioned above with their 600 use cases last year? In private, this year they showed vendors a slide with an undulating sine wave that represented their view of standards profitability implying only the even numbers make money…

Use Case?

Below is a list of 17 Use Cases for 5G networks that we came across at MWC this year. We compiled these from displays in the operators' and equipment makers' booths as well as conversations at the show. We used the titles provided in the booths.

- **Smart Stadium –** Augmented reality for stadiums. Hold up your phone or AR goggles and see more information about players and the action on the field (plus ads). 5G is needed here because of the density of simultaneous users.
- **5G Air Taxi -** When can we go back to calling air taxis helicopters again? We do not need 5G to control autonomous aircraft, but we will need 5G to navigate and manage massive swarms of semi-coordinated autonomous aircrafts.
- **Car to car signaling –** Autonomous cars will have the ability to avoid collisions built-in, but the whole system needs some form of coordination and information sharing. The reduced latency and larger number of simultaneous users available with 5G makes this the preferred technology, but not the only option.
- **HD Mapping –** There is a land rush on right now to map the world. We are already familiar with those sensor-laden cars driving around picking up all kinds of imagery and other signals, but there is need for even more. As we start adding more sensors to ordinary vehicles, there is a need for more bandwidth from 5G to be able to capture all that data.
- **Responsive video calls -** Video calls with an added layer of data on top allowing callers to add graphics to their videos. Probably works with 4G.
- **End to end open source experimental chain –** Changes to the standards for the core network allow for much greater use of open source technologies inside the core. The experimental piece implies a high degree of uncertainty of the path the operators will end up using inside their wired networks.
- **Industrial robots -** This seems to be a big push from equipment vendors. Building 5G networks into factory floors. This could in theory be done with 4G or Wi-Fi, but

5G offers better reliability, lower latency and a greater number of simultaneous devices.

- **Network slicing -** This is one of the biggest and most contested use cases held up for 5G. The idea is that networks can be divided up for different users. Premium customers could pay more for better quality of service or even their own **private network**. While 5G allows for this, it remains very unclear how it will be deployed and who will actually need this.
- **Personal Assistants –** The demo we saw of this showed tourists using a 5G network to get information about a new city they are visiting. Even the carrier employee hosting the demo admitted this could probably be done with 4G.
- **Advanced Ambulance Transportation -** This falls into the category of remote medicine, using advanced video and telemetry from monitoring equipment to connect a patient in an ambulance to a doctor. Could be done with 4G, but 5G adds better quality of video and greater bandwidth.
- **Remote controlled construction equipment -** The lower latency of 5G gives better response times between the controller and the equipment. Useful in dangerous settings, but unclear how this would be deployed and the size of demand.
- **Automated Farm Management –** Connecting up all the sensors and animal trackers on a farm. Interesting idea, can probably be done with 4G or some simpler, private radio networks. We saw China Mobile demo a Sheep Tracking app almost ten years ago. Also completely unclear how this gets sold or deployed.
- **Smart Cities –** This is the ultimate catch-all. In theory, this means better management of urban spaces by connecting all the traffic lights, cars, parking meters, and other sensors. In practical terms, it is completely unclear who builds this. Neither the operators nor city governments have the technical expertise to put this together, nor is it clear anyone else does either. Cities have had wired connections to many of these things for 50 years, adding wireless gets another layer of sensors connected, and in theory 5G expands the number of devices that

can be connected. But the value in doings this is very unclear. Also, for many countries, smart cities are a euphemism for mass video surveillance.

- **Connected car –** This is another catch-all. Many in wireless hope that wireless has a big role to play in the autonomous car future. However, the actual number of applications for wireless in that future is unclear. We will need some signaling between cars, and some systems to coordinate autonomous fleets, but this is pretty far in the future.
- **Next generation communication –** a euphemism for augmented reality. Once (if?) AR becomes real, wireless devices will need to draw down a lot more data and send up lots of real world images for analysis in the cloud. AR is still many years away, and really the case for 5G here can just be read as "more bandwidth". We can lump many other use cases in here including transmission of HD video signals to movie theaters and Virtual Reality (VR). Unclear why or how much of this will be done with 5G.
- **Security -** this is obviously a big topic. In the use cases we saw, this mostly translated to video surveillance, which can be accomplished with existing technologies.
- **5G Blimps –** A fleet of 5G, autonomous dirigibles. Worth mentioning because everyone loves blimps, except when they are being used to conduct mass video surveillance.

We could go on, as mentioned above one operator has a list of 600 of these. However, we think there are some clear themes. 5G delivers:

- **Greater bandwidth –** More bandwidth, or more users with the same bandwidth. This is obviously desirable. However, we think operators are confusing what users will do with this bandwidth with them playing a role. Historically, operators have had a poor track record in making these kinds of predictions. Ultimately most of the use cases will be decided by others – like app and software developers. It is also important to remember that much of this bandwidth improvement is

accomplished via allocation of new spectrum, just throwing more resources at the problem.

- **Lower latency -** the amount of delay in the communication between the mobile device and the operators' network. This is nice-to-have but only accounts for a small part of the total communications delay. Once a signal reaches the operators' networks there are still many more network and compute hops required as messages get sent around the Internet. Those legs of the journey carry a far larger amount of delay and 5G has no impact here. In theory, the reduced latency will give service providers incentive to install servers inside the operators networks which could be important in the balance of powers in the industry. That being said, many of the use cases operators are using to demonstrate reduce latency strike us as impractical, at best.
- **New network configurations –** The most prominent of these is the idea of network slicing. In our conversations no one had a good sense of how widely these will be deployed and how big demand is. We suspect that the far bigger impact will come inside operators' networks, allowing them to better manage their own networks through the use of more modern software techniques.

5G Components

Earlier, we have laid down a fairly sober case for 5G deployments. This standard, like all the others, will take a few years to roll out. That does not mean the next few years will be boring to watch. The extended effects of roll-outs always play out in hard to predict ways throughout the industry. The transition from 2G to 3G knocked several dozen chip vendors out of the industry. The handset industry in 4G is comprised of totally different players than it was in 3G. Many of those changes can be tied directly back to the change in the standard.

Let's examine three parts of the industry to see what changes may be in store.

Equipment Vendors

The network equipment industry has been in tumult for a long time, but have reached something of an equilibrium lately. There are four major telecom equipment vendors – Ericsson, Huawei, Nokia and ZTE. Ericsson has led the industry for years in terms of market share and market positioning but is under a lot of pressure recently. Nokia has rolled up all the smaller vendors (Alcatel, Lucent, Nortel and Siemens) giving it considerable scale. As one commentator told us, "So long as they do not do anything stupid they could do very well with 5G". Huawei and ZTE have made incredible gains over the past decade, but are obviously now dealing with a very challenging political environment.

All of this points to the potential for no change in the status quo with 5G. They should all benefit from the 5G roll out as carrier capex for higher-margin new products emerge. Of course, nothing is going to be that simple.

Both Ericsson and Nokia are on their back foot, contending with broader industry changes. Both face a grueling onslaught in the marketplace, from Huawei in particular. They are also up against important changes to the way the world builds network. These companies once dominated a major industry, but increasingly telecom networks look the same as all the other networks, aka the Internet. The 5G standard exacerbates this trend by making the core network much more hospitable to this more common approach to networking. This has eroded their technological advantages. Neither company has a

robust ethernet switching business, and neither company has a clear way to compete in the “cloud market”.

This matters a lot because even the biggest operators are succumbing to the Cloud wave and moving large chunks of their IT capabilities to the cloud providers. We heard a report that both AT&T and Verizon each spend a $1 billion a year on AWS. This means that Ericsson and Nokia are being pushed to compete at the edge of the network, particularly in base stations, aka the Radio Access Network (RAN). Not surprisingly both companies talked a lot about Edge Computing at MWC. Unfortunately, the RAN is the area where Huawei and ZTE have squeezed the European companies the most. Put simply, they are squeezed between the Cloud and China.

To make matters worse, several people told us that neither company is actually ready for 5G yet. Their roadmaps are up to a year behind Huawei and ZTE. It is hard to imagine either Ericsson or Nokia being forced out of the industry, but this protection rests partially on the political situation, and less on their competitiveness. They still have considerable capabilities and solid customer relationships, and should eventually win a lot of 5G business.

Handsets

For many years, the handset vendors have been the least inspiring part of MWC. Dozens of almost identical black bricks. This year was little different.

The companies largely displayed two types of new products: 5G phones and foldable screens. We are going to predict that market for 5G phones will look identical to the market for 4G phones. The advent of the standard will do little to change the shape of the industry.

Sadly, the same is true for foldable phones. We say sadly because this is some impressive technology. Five or so vendors had bending phones on display in their booths. They look incredible. They also look very fragile and not entirely practical. It would be nice to have a fold-out giant screen for gaming or work, but we suspect the ultimate utility of these devices will rest on their durability more than anything else. If the phones can withstand drop tests and repeated folding we may all own one someday, and that would

theoretically advantage companies with in-house screen capacity (e.g. LG, Samsung, TCL). However, no one has begun answering those durability questions, and we did not fail to notice that all of these phones were displayed behind glass.

Semiconductors

The biggest wild card for 5G will be modems. There are four merchant modem (or baseband) vendors today – Intel, Mediatek, Qualcomm and Spreadtrum, and two major in-house designers Samsung's Exynos line and Huawei's HiSilicon subsidiary.

A key learning from the show, confirmed by contacts at both Mediatek and Qualcomm was that Huawei's Balong 5G modem has the best performance on the market currently. Stunning news. Qualcomm has a second generation 5G modem sampling now which will likely level the competition, but still impressive and somewhat stunning that HiSilicon has made such gains. That being said, neither Exynos nor HiSilicon will ever be widely adopted by other handset vendors.

At the other end of the surprise spectrum (which is to say completely unsurprising) is that Intel's 5G modem was nowhere to be seen at MWC. Our annual ritual at the show for a decade has been to visit the Intel booth on Day One and look for their modem. Sometimes they have a giant box with pre-production silicon running in it, but this year, they did not even have that in the booth. Press reports ahead of the show said we cannot expect Intel's 5G modem until 2020. This means that they are going to remain 100% reliant on their sole customer – Apple.

Qualcomm had a strong showing this year. They announced their second generation 5G modem, sampling now, in phones by the end of the year. There were something like 20 Qualcomm-powered phones at the show. There were also 5 phones with Qualcomm modems for 5G mm wave. This is the next phase of 5G deployments, and these phones are impressively fast. Sony, for instance, had a demo showing their mm-wave phone clocking 2 Gbps downloads. The engineer minding the behind-glass demo said that the phone could actually go even faster but would overheat if they turned it up. (Not unreasonable for an early demo.)

More surprising was the news that Mediatek's 5G modem is close to readiness. They typically lag the launch of new standards by a few years, but closed the gap with 4G and now appear even closer with 5G. This matters as their core market, China, is likely to be among the earliest to have widespread 5G coverage.

We did not meet with Spreadtrum at the show. They tend to lag Mediatek, so 5G is not as relevant to their positioning right now.

In past years, handset vendors' prospects depended heavily on access to modems for new standards, which gave a big advantage to Qualcomm who typically had the first modems on the market.

This pattern now appears to have changed. The two largest handset vendors by market share have internal modems. Huawei appears to be moving to 100% use of HiSilicon, which is made more viable given the company cannot sell phones in the US. Samsung looks set to continue its recent trend of mixed use of internal and Qualcomm modems. The Chinese handset brands – notably Oppo/Vivo and Xiaomi – will remain major Qualcomm customers, but even here the advanced readiness of Mediatek means we will likely see those brands split their purchases as well.

So while historically, the advent of a new standard has meant several years of good times for Qualcomm, with 5G the market will be much more competitive. Qualcomm likely still holds a meaningful performance edge over its competitors (although that HiSilicon data point should ring a few alarm bells in San Diego). Many carriers are still restrictive in allowing Mediatek and Spreadtrum devices on their networks. And the major brands care a lot about performance, favoring Qualcomm. Nonetheless, the company now faces a reduced addressable market.

Which of course leads to the question everyone is asking…

What will Apple do for 5G?

Apple does not exhibit at MWC, but they are definitely there both in person and in spirit. While Apple engineers made the rounds of the vendors' booths, the question that everyone wanted to know is when will there be a 5G iPhone?

And no one knows the answer.

Our current view is that there will not be a 5G iPhone in 2019 and probably not in 2020 either.

Here is the narrative.

Apple is currently using Intel for all of its modems. They can't or won't buy modems from competitors Samsung and Huawei. Mediatek and Spreadtrum cannot meet Apple's requirements. And of course, Apple and Qualcomm are doing their best to fill up the college fund for the children of every Intellectual Property lawyer on the planet.

The problem for Apple is that Intel's 5G modem is not ready, and looks like it will not be ready until next year, at the earliest. Intel has always struggled with its modem, especially during periods of standards transition. This time around the company appears to have also suffered a serious loss of high-level management members from its modem team (some of whom went to Apple).

So Apple likely faces a pretty serious choice. They either need to delay the launch of a 5G iPhone or find an alternative supplier.

Let's consider those choices individually.

Is delaying the 5G iPhone serious? Recall that the original iPhone was only 2G even though the industry was already deep into 3G. And as we have noted elsewhere consumers have little reason to care that much about 5G. The standard will not bring giant increases in bandwidth. This gives Apple some room for delay. The lack of 5G in this year's iPhone will be mocked in the Tech blogosphere but will likely have zero impact on sales. But what if there is no 5G in next year's iPhone? That will undoubtedly add fuel to the perennial "Apple has lost its touch" headlines, but that may be just a small marketing problem. On the other hand, differentiation in the smartphone market is hard for all vendors. Everyone

has the same combination of sensors and cameras and form factors. The lack of 5G in an iPhone will be noticed by consumers at some point.

This also poses an interesting shift in power dynamics. For the first time ever, the operators now have some leverage over Apple. It is not lost on us that the US carriers are among the most vocal about pushing 5G into the market as soon as possible. There is also an important dynamic in China. Apple is now clearly struggling there, and it looks likely that Chinese operators will be among the first to deploy 5G networks. If Apple's hold over the imagination of its customers is already being heavily tested, the lack of a 5G iPhone will eventually become glaring in that major market.

So delaying a 5G iPhone is not an imminent problem, Apple could risk delaying 5G until 2021, but eventually consumers will take notice. Given the perception of their vulnerability waiting that long is a big risk.

So what can Apple do? We see four options.

First, they could take a flier on a Mediatek 5G modem and release an iPhone on that next year. We see this as highly unlikely. The companies currently have very limited commercial interactions. Apple is not satisfied with the quality of Mediatek's modems. And taking Apple on as a customer would require a significant investment for Mediatek for a customer that is incredibly demanding (to put it diplomatically). It is not clear that this is something Mediatek can or even wants to do.

Second, Apple can roll the dice and pray Intel gets its modem working on time. This is possible, but Intel's history here is not encouraging. While past performance is no guarantee of future results, the technical challenges for Intel are immense. Apple may see this as the least bad option, but they would be gambling on a vendor that has a very bad record of delivering to Apple's timetable (and let's not even discuss their ability to advance to 10nm chip production).

Third, Apple can build its own. We wrote about this last month. They are hiring 500 people in San Diego this year and another 500 next year, which likely means they are trying to poach modem engineers from Qualcomm. It appears that Apple's modem effort is still in very early stages. Most estimates we heard was that it will take at least three years for

them to develop their own modem from scratch. Even if we give them an Apple Miracle discount, it is still really hard to see them finishing their modem in under two years. Which again leaves us with a 2021 5G iPhone. From Apple's point of view, they may feel that since they have to build their own modem eventually they might want to take the hit now and go all-in on the internal solution. Their major competitors are already there. The biggest concern may be the operators. Even if Apple can build its own modem in record time, it will still need to get certified by the operators (especially in the US). At the best of times this is a time-consuming process, but it also gives the operators considerable leverage over Apple.

We are also giving Apple the engineering benefit of doubt here by assuming that they can build a modem. Both Huawei and Samsung have thousands of network engineers to help them build these highly complicated chips. Apple may find it much harder to build than they anticipate. Their track record here is mixed. True, their A-Series application processors lead the industry, as do many of their other internally-built chips. But they have struggled with connectivity. Years ago they bought a Wi-Fi/Bluetooth team from Texas Instruments, but that effort appears to be have floundered, and Apple still buys other people's products for these chips. We imagine that Apple will get a modem built, but it may not be as easy as we are assuming here.

Fourth, the company can go to Qualcomm. This would first require a settlement of the legal issues. Qualcomm has clearly indicated that part of its legal strategy rests on this 5G chokepoint adding time pressure to negotiations with Apple. On the legal front, Qualcomm is awaiting their court case against the US FTC regulator. Then they have their own case against Apple coming to court in April. We have no way of gauging the outlook for either case, but the timing does not help. No settlement is likely until after the FTC ruling. If it goes Qualcomm's way, we could see the two companies settle before April. If the ruling goes the other way, a lot of things will happen, but it may encourage Apple to forego settling ahead of the April case.

Our point here is that even if Apple and Qualcomm settle this Spring, it will take many months to design a Qualcomm-powered 5G iPhone. There is no way it could be ready this

year for a September launch. It could work for the 2020 iPhone, but the timeline is already tight. If the two companies do not settle by the end of the year there will probably not be enough time to accomplish that either.

There is probably a fifth option. Apple could fudge the whole thing by claiming that next year's iPhone is "5G". There is already a lot of confusion among consumers about what 5G is. AT&T is not helping matters by attempting to label its advanced 4G network as 5G. Apple could add a few 5G-ish features to their 4G modems and most consumers would be satisfied. This would relieve the marketing problem for at least one cycle, but it lacks a 100% adherence to reality.

All of this has the potential to be a big problem for Apple. A 2021 date for a 5G iPhone will be a big marketing problem, even if consumers are barely aware of 5G at that point. The problem is especially acute in China where Apple is already struggling. To be fair, this is not an existential threat right now. People will buy iPhones for a long time, locked in by consumer preference and software ecosystem. But eventually, the marketing problem will grow and insert itself into consumer awareness, affecting sales. Apple does not have great options at this point, but they still have a window to sort out.

Over the longer-term, this will clearly convince Apple that it has to build its own modem so that they never have to rely on outsiders again for such a key component.

The Operators and the Enterprise

As denizens of Silicon Valley we tend to be skeptical about the operators, and many we know are downright hostile. In general, when we work with start-ups we caution them to avoid getting involved with operators. The sales and partnership cycles can consume more time and engineering than most start-ups can afford. As a result of much past experience the Valley tends to think of carriers as 'dumb pipes', when they think of them at all.

This year, we ended up spending a lot of time at the show speaking with telecom operators. And while we would still be cautious about sending start-ups to work with them, we think it is worth understanding things from their point of view.

Our sense is that most wireless operators live under a cloud of fear. They are the focus of considerable consumer and government scrutiny. Despite providing an important, powerful service, they are more often viewed us rent-seeking monopolists. They are also undergoing tremendous technological change. Many of the services they once provided are now done better by others. Messaging apps have not replaced SMS text messaging, but already carry far more volume collectively than the operators' systems. The big cloud service providers build their own networks up to including laying their own submarine fiber optic lines. Even gaming companies engage in very telco-like activity.

So smart people at the carriers have some reason to worry about their future. Telecom companies will always be needed, but these once dominant giants do risk being pushed out of many profit pools and forced into smaller and smaller value domains.

Will 5G change any of that? Probably not, but there are some changes coming that will help. Most people focus on the bandwidth side of 5G. Over time, the new standard will increase networks' data capacity and speeds. While useful, these improvements have been going on for decades and do little to alter the overall strategic direction of the industry. Moreover, the big increase in capacity will only come from deployment of mm-Wave parts of the standard which will require a massive installation of small cells. In the short term, this is just one more cost for the operators to bear, and most of them appear to be in no hurry to deploy.

One portion of 5G that no one is highlighting is the fact that much of the promise of 5G depends the use of new spectrum bands. This means the operators are not becoming more efficient, they are just deploying more assets. Spectrum is not cheap. Many of the gains of the past standards are rooted in greater efficiency of existing spectrum. Hence the commonly heard refrain at the show "The operators only make money on even-numbered G's". The 3G standard brought many new spectrum channels into use, and the purchase of those bands almost bankrupted the operators. The 4G standard used new bands, but offered operators much greater efficiency in bands they already used. The risk is that 5G requires big spectrum purchases which only start to be profitable in ten years.

So instead the operators are betting their 5G investments will get enterprises to use wireless in new ways. Hence all the exhibition floorspace dedicated to smart factories, robot bulldozers and autonomous cars.

The operators and equipment vendors are hoping that big companies will deploy mobile systems in new ways. This has two problems. The first is that it is unclear why we need 5G for much of this. Of the dozens of enterprise use cases we saw at the show, most could probably be handled by 4G, or even Wi-Fi. Those standards have deficiencies when compared to 5G but work well in most cases. Convincing enterprises to move beyond good-enough will be challenging, and the true 5G use cases may be fairly limited in number.

The bigger problem is how this capability gets sold. Operators have a very weak enterprise sales function. For most carriers today, enterprise sales is focused on selling mobile phone bulk plans for employees. The sale of 5G Use Cases requires a radically different approach because the connectivity piece of the use case is just a small part of the solution.

Take 5G 'Smart' Factories. Using 5G here might make sense for a large factory as the number of connected devices is large, latency matters, and industrial conditions can be a problem for Wi-Fi. But who will build the actual factory machines? Who designs the radio modules that go in them? What software is used to manage all of it? There are dozens of vendors involved. This is really a problem for a Systems Integrator (SI), and the operators

lack this capacity. The equipment vendors have some experience as SIs, but only in conjunction with building out wireless networks. Nokia, for instance, announced a large partnership with German industrial giant Bosch, which gives a sense of the scope of the ambition. But even here, Bosch is just solving a small part of the puzzle, and manufacturing is just a single vertical, among dozens.

And we have reason to be cautious about this. The operators have been trying to do something similar with IoT for a decade (or more, remember M2M?). There they face the same problem of a complex sale across dozens of heterogenous industries, and the end result is fairly uninspiring to date.

We are not saying the operators are incapable of adding sizable enterprise revenue streams, but it will be very challenging. At best it will take a very long time to realize. In practical terms, it will require building far larger partner ecosystems, and the operators have never been able to do this well.

Should we all mourn the decline of the operators? No, that is not going to happen. Mobile networks are hard to build, and we are lucky to have the systems we enjoy today. After all, when was the last time your mobile bill went down? The operators through their ownership of scarce spectrum resources will always have a role to play. That being said, their ambitions to radically transform themselves seem unlikely to arrive.

Travelogue - Homage to Barcelona

We always like to close these notes with a few random notes on interesting if less significant findings at the show.

This year we would be remiss if we did not pay tribute to the City of Barcelona. We know from people's questions that the outside press gave the impression that the city was a travel nightmare during MWC, due to a Metro strike. In reality, we saw the opposite.

The strike did not seem to impact travel times. Getting in and out of the show this year was the easiest we have seen in the 14 years that we have been attending. The organizers exerted a massive effort on this front. For instance, at every major metro interchange there were rest-vested MWC employees directing showgoers. Not only on the platform, but at every junction in the interconnecting hallways.

Security at the show was dense without being obtrusive. As were all the other key metrics of organization.

We could quibble with the quality of the food or the biometric, face recognition software at the entrance ways. But these were minor and should not distract from the fact that the show organizers and the city did a really good job.

Every time, we heard someone complain about some aspect of the show, we asked "What would the show look in New York City?" Or Las Vegas? Having 100,000 visitors descend on your city for a week is not easy, and Barcelona has done a great job of supporting the show.

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