


ON THE TECHNICAL FUTURE OF THE TELECOMMUNICATIONS INDUSTRY

IMPLICATIONS AND GROWTH OPPORTUNITIES FOR OPERATORS FROM
THE DEVELOPMENT OF FIXED AND MOBILE NETWORKS



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Telecom network operators over the past years have watched revenues stagnate, in spite of a massive increase in bandwidth demand and usage. In this article, we project the development of network technology and consumer demand, first in fixed broadband and then in mobile broadband, and show how network operators can profit from future development and achieve revenue growth again.

This Point of View aims at answering crucial questions telecommunication operators will face going forward:

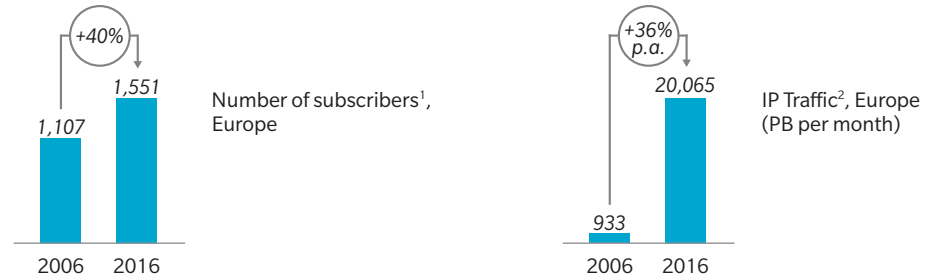
- Where will revenue growth come from in the future?
- What are likely to be some of the technical developments in bandwidth and connections, both in fixed but especially in mobile?
- What trends will drive demand for fixed-line and mobile services?
- Will the technical development of mobile networks keep pace with the demand?
- What are the implications for the future of mobile-only operators, and will there be a revenue upside, such as from scarcity pricing?

WHERE WILL REVENUE GROWTH COME FROM IN THE FUTURE?

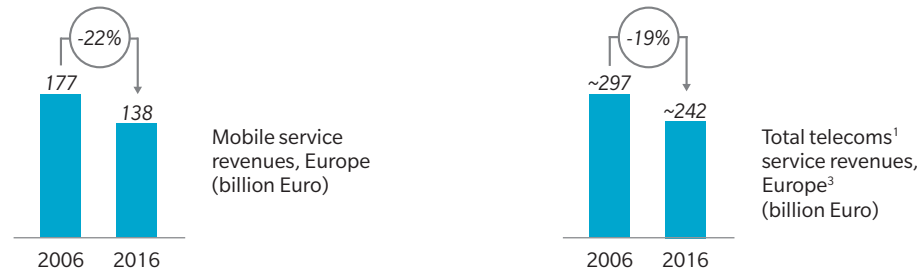
There exists a massive gap between the underlying growth in customer-base and data traffic, and the growth in revenue for telecom operators. (See Exhibit 1.) Over the past 10 years, the number of mobile subscribers in Europe has grown by 40%. Data traffic has soared in both fixed and mobile broadband, increasing at an average annual rate of about 36%. Yet when measured against revenues, the picture is bleak: In Europe, mobile-service revenues have shrunk 22%, and results for the total telecom market, including fixed line operators, is almost as bad.

Exhibit 1: Where shall future revenue growth come from?

PHYSICAL DEMAND IS GROWING STRONGLY...



...BUT IN REVENUES THE PICTURE LOOKS RATHER DIRE



1. Mobile, fixed voice and broadband

2. Includes Fixed Internet, Managed IP, Mobile Data

3. Incl. Turkey, excl. Russia, Ukraine

Source: Ovum, ETNO, Cisco

Telecom operators have tried pulling different levers over the years in an effort to counteract this problem and produce revenue growth. (See Exhibit 2.) They have tried raising rates, launching takeovers with an eye to consolidating the market and driving rate increases. They have lobbied for lighter, more benign regulation (especially in the area of wholesale rates), and have expanded into new markets outside their core connectivity business.

Exhibit 2: Where shall future revenue growth come from?

LEVER	FIRST ASSESSMENT
Price increase (without consolidation)	<ul style="list-style-type: none"> Has not worked in the past. Small players with (real or perceived) elasticity of < -1 and access to expansion financing will seek to gain markets shares Large player's management incentivized personally to achieve even small market share gains ("market leader", "outsmarted competition", etc.)
Consolidation (followed by price increases)	<ul style="list-style-type: none"> The jury is still out on the results, but looks promising. 3-player market minimum apparently. Regulatory behaviour and remedies decisive. Logic above on price increases still holds in many cases
More benign regulation (wholesale prices, termination rates, consolidation approval, investment security, etc.)	<ul style="list-style-type: none"> Obviously main lever Lots of effort into it Some progress, but unclear sustainability
Expansion into new products/ services/markets	<ul style="list-style-type: none"> New products have been less profitable in adjacent markets, e.g. TV Global economies in R&D would be needed for global OTT services, e.g. messenger
Profit from future development in the core business, i.e. connectivity	CORE OF THIS POINT OF VIEW

Nevertheless, telecom operators have not been able to make price increases stick. The reason for this is twofold: Firstly, many smaller operators have responded to price increases by undercutting the hike, hoping for market share gains; secondly, the performance of management at many of the bigger incumbent players is de facto measured on the basis of market share and they are therefore incentivized to maintain market share.

Consolidation is probably the most powerful lever available to telecom operators to increase prices again. But regulators have blocked mergers and takeovers (as in the UK). Or in those cases where the mergers were allowed to go forward, regulators have insisted on remedies that resulted in the larger merged companies having to give up a part of their network capacity to a smaller existing player (as in Germany) or that ended in the creation of a new player (as in Italy). Either way, the outcome reduced the likelihood of any price increases.

Finally, new markets such as IPTV, which operators hoped would boost revenues, have proven less profitable than the core business, or else have turned out to be near impossible to penetrate when competing with global OTT players, such as Google, WhatsApp, and Facebook.

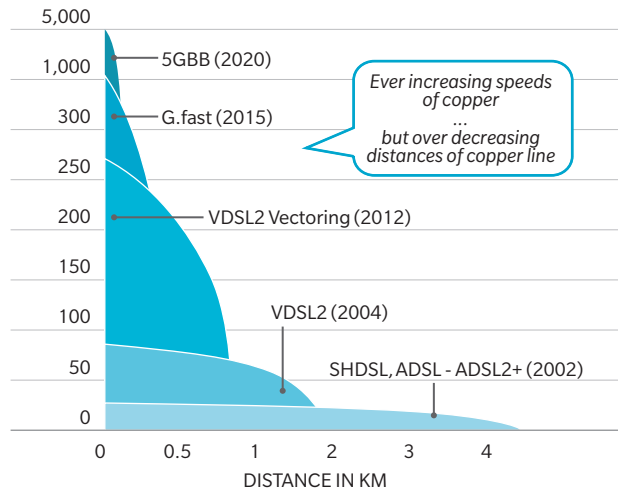
The question, therefore, is whether there exist growth opportunities beyond the aforementioned levers, coming in the next few years from technical developments in operators' core connectivity business that would lead to "natural" levers that cannot be taken away by regulation.

TECHNICAL DEVELOPMENT OF CONNECTIONS AND BANDWIDTH IN FIXED-LINE BROADBAND

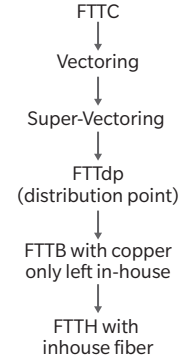
The development of bandwidth in fixed line via copper, cable, and fiber would seem predictable. The technical development for data transmission via copper over the past 15 years has increased bandwidth significantly. But improvement in speeds over copper wire has come at a cost: the ever-decreasing lengths of copper along which it is feasible to transmit data at that speed. (See Exhibit 3.) Therefore, the huge copper stock in the ground can only be used for future high bandwidth connections by laying fiber closer and closer to customers and thereby decreasing the length of the copper lines employed. Line technologies as Fiber-to-the-Curb (FTTC) and Fiber-to-the-distribution-point (FTTdp) and transmission technologies such as VDSL, Vectoring, Super-Vectoring, G.fast do exactly this. Nevertheless, these are clearly intermediary solutions, designed to buy time to recover high investment costs in line technology (mainly digging), before finally rolling out Fiber-to-the-Building or even Fiber-to-the-Home (FTTB/FTTH).

Exhibit 3: Technical development bandwidth copper

MAXIMUM SPEED VIA COPPER
BANDWIDTH IN MBIT/S



Fiber ever closer to the households with copper length decreasing:



Source: BMWI, Huawei Technologies, Kabel Deutschland, ct, DSL Forum, Oliver Wyman Analysis

Coaxial (TV) cable can carry higher frequency signals over longer distances than copper, but its theoretical bandwidth has barely budged over the past about 10 years. (See Exhibit 4.) Coaxial cable will be replaced by optical fiber someday, but with a total bandwidth of about 10 Gbit/s in data able to be transmitted over cable in the upcoming DOCSIS 3.1 standard, there is ample room for future applications in the coming years.

Exhibit 4: Technical development fixed bandwidth cable (coax)

COAX (CABLE)

Nearly **stagnating** development of **theoretical bandwidth**:

- **2009**: ~100 channels × 8 MHz/channel × 10 bps/Hz¹
→ 8 Gbit/s (sum of up and down links)
- **2016**: DOCSIS 3.1 (frequency up to 1.794 MHz; higher modulation): **10 Gbit/s** down, **1 Gbit/s** up

2016 typical bandwidth high-end user, residential (downlink):

0,4–0,5 Gbit/s

e.g. Japan, South Korea, Sweden, Norway, Romania, Switzerland

Hypothesis

CoAx (cable) still **competitive** in the **next 3–5 years** (DOCSIS 3.1 coming in 2016/2017, even though delayed) – but **afterwards** being **replaced by fiber**

1. 256 QAM Modulation

Source: IDATE for FTTH Council Europe, February 2016

With optical fiber, there is practically no bandwidth limit. (See Exhibit 5.) Currently, the typical bandwidth for a high-end residential user is 1 Gbit/s in advanced countries like Japan, South Korea, Sweden, and Norway. FTTH/FTTB penetration is growing as well, with more than 30 percent of households in those countries already connected via optical fiber. Moreover, existing speed limitations for consumers will be easily overcome with the passage of time, as speed is driven by the availability of cheap mass market equipment, server connections, network backbone, and marketing considerations, and not by technical boundaries in the last mile with FTTH/B.

Exhibit 5: Technical development fixed bandwidth fiber

FIBER (FTTH)

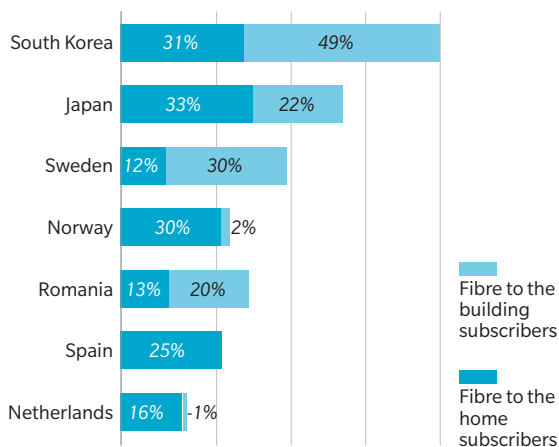
In principle no limitation to bandwidth on the last mile

2016 typical bandwidth high-end user, residential (downlink):
1 Gbit/s
 e.g. Japan, South Korea, Sweden, Norway, Romania, Switzerland
 FTTH also **major weapon** against cable in those countries

Still existing speed limitations for consumers driven by availability of mass market equipment, server connections, backbone capacity, marketing considerations, etc. – but not by last mile

RAPID FTTH DEPLOYMENT ACROSS THE WORLD

FTTH (and FTTB) penetration 2016



Source: IDATE for FTTH Council Europe, February 2017

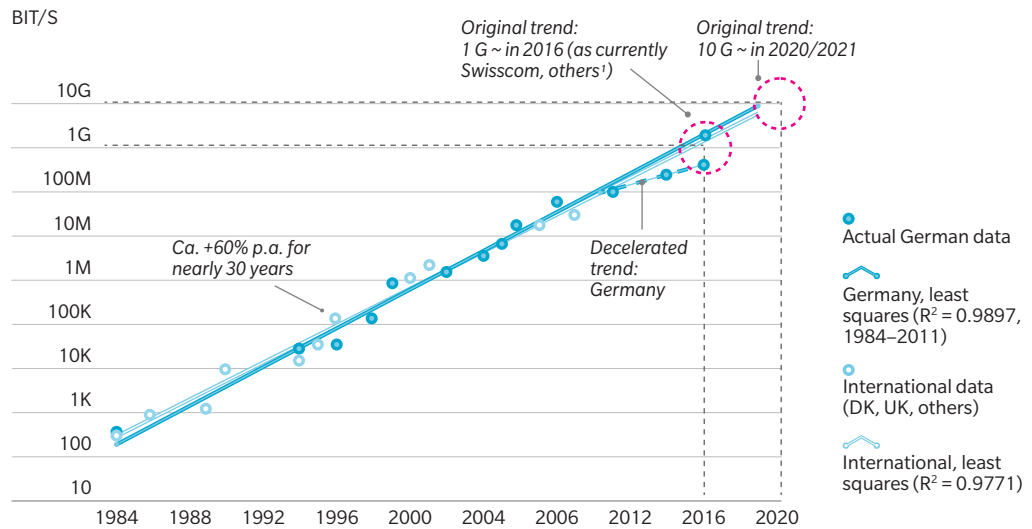
But how fast will demand for bandwidth actually increase? And moreover, for how long will intermediary technologies like FTTC, FTTdp prevail before consumer demand for higher speeds reaches a tipping point that can finally be satisfied only by FTTH?

To answer this question, we looked at the development of historical bandwidth for high-end residential customers in select countries, such as Denmark, the UK, Switzerland, and Germany from dial-in modems in the mid 1980s to today's technology. (See Exhibit 6.) The trend on the logarithmic scale follows a quite constant growth of about 60% per year, over a period of 30 years in those countries that today offer FTTH with 1 Gbit/s, as is the case with Switzerland (Swisscom).

This extrapolation into the future also implies that already in around five years, high-end residential users will have access to download speeds of 10 Gbit/s. Such speeds are well beyond the limits of technologies like FTTC/FTTdp (VDSL, Vectoring, etc.), and exist at the limit of coaxial cable. In countries where FTTH/B has not been built out, such as Germany, cable operators based on the DOCSIS 3.0 standard have taken the lead in download speeds, and growth has reduced to about 40 % per year since the beginning of the 2010s.

Exhibit 6: Current top end bandwidth of 1 Gbit/s is in line with historical development – this would mean 10 Gbit/s in ca. 4–5 years already

FIRST TIME OFFERED BANDWIDTH (FIXED NETWORK, DOWNLOAD)
HIGH END RESIDENTIAL CUSTOMERS, GERMANY, DENMARK, UK



1. E. g. in Japan, South Korea, Sweden, Norway, Romania
Source: International Data: Nielsen, <http://www.useit.com/alertbox/980405.html>; German data and least squares: Oliver Wyman

WHAT ARE THE DRIVERS OF DEMAND FOR FIXED-LINE AND MOBILE SERVICES?

To answer this question we looked at three interrelated questions: What has driven demand for ever-greater bandwidth in fixed-line services in the past? Will this trend prevail in the future? And can this trend be transferred to mobile services, albeit with a time delay as has been the case historically?

The main drivers of bandwidth consumption have been faster processor speeds and greater storage capacity (both of which are driven by Moore’s law, which states the number of transistors on a microprocessor chip will double every two years or so), and also bigger screen sizes and higher screen resolutions. (See Exhibit 7.)

Exhibit 7: Demand drivers fixed and mobile

MAIN DRIVER FOR THIS STRAIGHT TREND HAS BEEN MOORE’S LAW – WILL FIXED AND MOBILE BANDWIDTH DEVELOPMENT PREVAIL?

TRENDS DRIVING NETWORK BANDWIDTH DEMAND AND SUPPLY	TRENDS PREVAILING IN FUTURE, FIXED LINE?	MOBILE USE CASES FOLLOWING FIXED WITH A TIME DELAY?
Faster processor speed (Moore’s law)	✓ Moore’s law will prevail another foreseeable 5–7 years, especially for storage size, less so for processor speed ¹	✓ Limits in Moore’s law by heat development will be remedied by cloud computing (which will lead to additional traffic) ¹
Larger storage size (Moore’s law)	✓	✓
Larger screen size (TV, tab, phone, ...)	✓ Growth will slow down, but not stop	⚡ Very unlikely in the mid-term future – long-term future different with self driving cars
Higher screen definition	✓ Development continues with 2K→4K→8K etc.	? Physical limits for human eyes will be the boundaries



Growth for fixed bandwidth will continue in the foreseeable future – but will demand growth for mobile bandwidth per user slow down?

1. Source: <http://www.nature.com/news/the-chips-are-down-for-moore-s-law-1.19338>

This trend for fixed line service is likely to persist for some time. Moore’s law will prevail for at least another five to seven years¹ when it comes to storage (it is less certain for processor speeds). And while growth in screens may slow somewhat, higher screen definition will continue, to 8K and beyond, until we reach the limit of the human eye’s ability.

Typically, mobile broadband development has followed the trends in fixed broadband, albeit with a delay of a few years. This will likely hold true for the future as well. Processor speeds will grow faster, according to Moore’s law, and limitations imposed by heat development will be remedied by shifting processing power to cloud computing (leading to additional traffic). Storage size will grow, too. The size of mobile screens, however, is not likely to grow much beyond current sizes, and screen definition will reach a limit on these smaller devices. Does that mean growth in the demand for mobile bandwidth per user will slow down as well?

We propose that the opposite will happen. Increasingly, a consensus is forming that the future use case for massive mobile broadband bandwidth demand will be virtual reality (VR), with live streaming VR, sharing over social media and immersive experiences. (See Exhibit 8.) The potential for growth in this market is enormous and radiates outward in many dimensions: cameras, headsets, and developer platforms. Social media giants such as Facebook see VR as the natural development and progression of the drive to share moments in one’s life: moving from text at first, then to photos and videos and, someday in the future, VR. Cheaper mass-market VR products like Samsung’s add-on to the Galaxy S6, S7, and S8 are already quite appealing. Future developments are likely to have 4K screens. High-end cameras already have 24 HD lenses with 120 fps, and high-end headsets now have 2 MM micro mirror arrays projected with low power LED on the retina. It may take a while for mass market products to reach consumers and there are a number of problems that need to be solved, such as the chicken v. egg in terms of content/hardware.

1 <http://www.nature.com/news/the-chips-are-down-for-moore-s-law-1.19338>

Other problems include too-short battery life, sensors in need of improvement, and an immature monetization model for early adopters dependent on ad sponsorship. But those problems will eventually be overcome – and VR will surge.

Exhibit 8: We think mobile data demand growth will continue – development will go towards mobile virtual reality

Future mobile use cases on Virtual Reality...

- “Share moments of life” – main shared info medium development over social media as Facebook will be from text → picture → video → Virtual Reality
- Life streaming, e.g. clips
- “Immersive” experience

➤ ...will likely be sharing

Current developments...

- Cheap mass market products as Samsung VR glasses (based on S6/S7) already “OK”
- 4K screens per eye coming soon
- High end cameras with 24 HD lenses, 120 fps
- High end headsets project 2m mirror arrays with low power LED on eye’s retina

➤ ...will lead Virtual Reality towards mass market

Current problems...

- Chicken-egg of content vs. hardware
- Battery life too short
- Sensors need to get better
- Difficult monetization for early adopters beyond sponsoring

➤ ...will be overcome with time



Demand growth for mobile bandwidth per user will prevail

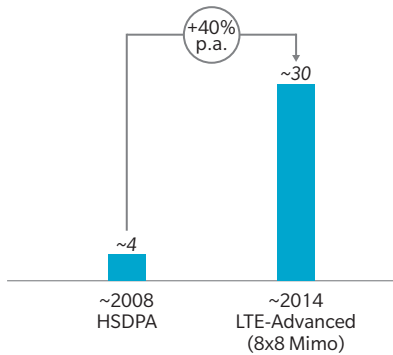
WILL THE TECHNICAL DEVELOPMENT IN MOBILE NETWORKS KEEP PACE WITH DEMAND?

While past developments, from 2G to 3G then 3G to 4G, involved increased spectral efficiency (bit/s per Hz) and more spectrum, 5G developers are mainly concentrating on more spectrum in higher frequencies to increase bandwidth.

Spectral (or bandwidth) efficiency gains have been impressive: For example, from 2008 (HSDPA) to 2014 (LTE-Advance), spectral efficiency has grown about 40 % per year. (See Exhibit 9.) Together with additional spectrum, this has led to peak mobile downstream growth in Germany, for example, of 60% annually over the same period – similar to the development in the fixed network. (See Exhibit 10.)

Exhibit 9: Mobile network development has especially increased the spectral efficiency over the past decade

SPECTRAL EFFICIENCY (BIT/S)/HZ; DOWNLINK

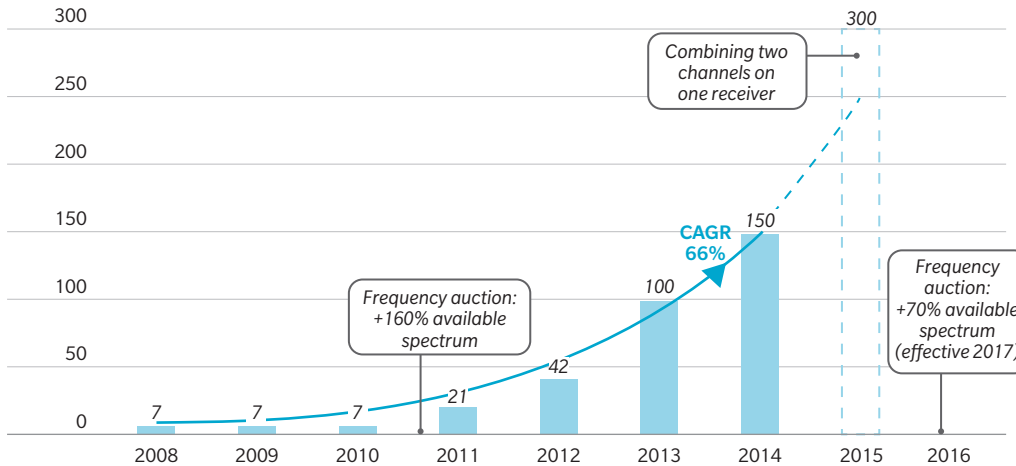


- Impressive progress, but significantly slower than progress in fixed line (+60% p.a.)
 - Therefore additional measures were needed and will be needed further:
 - More spectrum (additional frequencies, refarming of old frequencies, carrier aggregation, use of unlicensed spectrum)
 - Smaller and more cells with higher frequencies
- And progress in spectral efficiency is supposed to decelerate further in 5G¹

1. Source: Nokia 5G white paper, 2015

Exhibit 10: With the help of additional spectrum, peak mobile downstream for German DT customers has been able to grow 66% yearly

PEAK MOBILE DOWNSTREAM AVAILABLE FOR DEUTSCHE TELEKOM CUSTOMERS IN GERMANY MBPS



This development is reaching its limit going forward, due to slower improvements in spectral efficiency, technical limits, and the limited availability of additional spectrum in the attractive 800–2.600 MHz range.

Therefore, a totally new approach leading to very different mobile networks in the future will be needed. Currently, the consensus is that the main gain in 5G mobile broadband will come from available spectrum in very high frequencies as 15/28/70 GHz, since there is more than enough available spectrum. But these mm/cm waves do not travel far (roughly 150 meters). With special antennae arrays, these multiple-in, multiple-out (MIMO) antennae will form beams that follow pedestrians, giving them 1-plus Gbit/s per customer. (See Exhibit 11.)

Exhibit 11: Looking forward though, the main gain will come from additional spectrum in very high frequencies in 5G

MAIN DRIVER FOR THIS STRAIGHT TREND HAS BEEN MOORE´S LAW – WILL FIXED AND MOBILE BANDWIDTH DEVELOPMENT PREVAIL?

Intermediate solutions in 4G world, e.g.

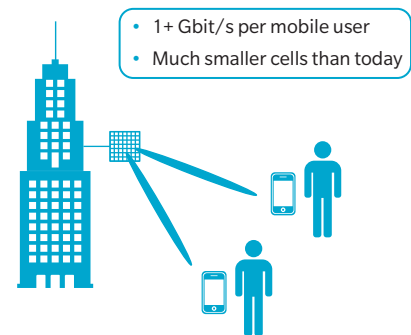
- LTE in unlicensed (also wifi) spectrum
- Aggregating spectrum (20, 40, 60 MHz)
- Using higher spectrum (3.5 GHz)
- Better modulation, more antennae

will **increase capacity**, but **not massively**

Main change will come with 5G:

- **Very high frequencies**, e.g. 15/28/70 GHz
- **Large additional spectrum** available, e.g. 6–10 GHz
- **mm/cm waves** not travelling further than ca. **150 m**
- Beam forming MIMO antennae, with **beams following the users**

5G – future development



Mobile radio access can keep pace with demand for many years ahead

Source: Oliver Wyman, Nokia, Ericsson, Fraunhofer

Real 5G rollout will not take place before 2020, so vendors and operators are now pushing for intermediate solutions to increase mobile bandwidth in the current 4G world, using LTE in unlicensed (also wifi) spectrum, aggregating spectrum (20 MHz, 40 MHz, and 60 MHz), using higher spectrum (5 GHz), better modulation, and more antennae. This, however, will increase capacity only modestly.

The real breakthrough in mobile access technology will come with 5G. Once this technology, which is still under development and in the process of being standardized, arrives, mobile radio access will keep pace with demand for many years to come.

WHAT ARE THE IMPLICATIONS, FOR EXAMPLE FOR THE FUTURE OF MOBILE-ONLY OPERATORS AND WILL THERE BE ANY REVENUE UPSIDE FROM SCARCITY PRICING?

The implications of this technical development will not only change business models but will also give operators the chance to price scarce resources accordingly and find a way back to growth.

The 5G radio-access technology described above is revolutionary, and it will also change the world of mobile operators when released. The vast number of small cells that will be needed due to the high frequencies (and on top, the need for – ideally – line of sight for the radio signal) will create a major challenge for the mobile backhaul. There will be a need of 10-plus Gbit/s connections to transport the traffic from/to the cells every 2-to-300 meters.

The solution to this problem is unclear at the moment, but there are three possible scenarios with dramatically different outcomes for competitive positions and revenue upsides. (See Exhibit 11 and Exhibit 12.)

Exhibit 12: Three possible scenarios for mobile backhaul with dramatically different outcome for competitive positions and revenue upsides.

SCENARIOS	REMARKS/IMPLICATIONS
1 Mobile backhaul would be “mobile” as well (same mobile technology)	Mobile only operators would be independent of fixed line or integrated operators and would have a bright stand alone future But “pure mobile” most likely not feasible – fiber as complement needed
2 Fiber needed for backhaul, fiber all over the place , e. g. in street lamps, on the walls of tall buildings, etc.	Coverage can only be reached by fixed/leased line operators , getting a massive push in whole-sale revenues and improving the business case for rolling out fiber to the buildings or to the homes Very critical development for the future viability of mobile only operators – either struggling to compete with integrated rivals or relying on the help from regulators for cheap wholesale access to fiber
3 Fiber needed for backhaul, but cannot be satisfied economically	Probably the most interesting scenario Increasing customer demand for growing data rates would hit an only slowly developing supply The only way for operators and regulators to optimize the collective welfare of consumers and businesses is to price accordingly such a scarce resource First opportunity in many years to raise prices and align physical and revenue growth again This implies foresight and discipline , esp. by the integrated/fixed line player, e.g. <ul style="list-style-type: none"> • Internal mechanisms not to “over-invest” beyond economic rationale • To spot the right moment, and • To seize the opportunity

Major challenge for mobile backhaul

- Vast number of very small cells needed, every 2–300 meters
- 10+ Gbit/s connections
- Ideally line of sight for radio signal

In the first scenario, mobile backhaul would be “mobile” as well, that is, it would be delivered by the same mobile technology with high-frequency beams in a row and crossing. Most likely, such an extreme scenario with “pure” mobile backhaul will not be feasible and will have to be complemented by fiber. But in this scenario, mobile-only operators would be independent of fixed-line or integrated operators and would have a bright stand-alone future.

In the second scenario, fiber would serve as the principal backbone for mobile backhaul. This would result in fiber everywhere, from public streetlamps to traffic lights to building walls. Such extensive coverage could only be accomplished by fixed-line (or leased-line) operators. In this scenario, fixed-line operators would see a massive surge in wholesale revenues and would improve the business case for rolling out fiber to buildings and to homes. Under the fiber-centric scenario, mobile-only operators would struggle to compete with their integrated rivals and would have to rely on the help from regulators for cheap wholesale access to the fiber in the mobile backhaul. This would be a critical development for the future viability of mobile-only operators.

In the third scenario, the strong demand for fiber could not be met in an economical manner, not even by integrated operators with synergies to their rollout of fiber to consumers and businesses for fixed services. This is the most interesting scenario: Increased demand for faster data speeds and more data would hit a wall caused by lagging supply growth. Data throughput in radio access and in the backhaul would be limiting factors and become a scarce resource. The only way for operators and regulators to optimize the collective welfare of consumers and businesses is to price such a rare resource accordingly. Obviously, this would imply some discipline on the part of operators not to overinvest in the backhaul infrastructure, to spot the right moment, and to seize the opportunity. But that would present operators with the opportunity to raise prices and align physical and revenue growth again for the first time in many years.

CONCLUSION

In the next five to ten years, demand in fixed-line broadband bandwidth will grow exponentially, leading to speeds that can only be supplied by FTTH/B. Mobile broadband demand will follow in parallel. Virtual reality is the “killer app” that will drive massive demand. Mobile broadband supply will begin to reach its limits, with spectral efficiency gains and additional attractive spectrum in the current bands not growing as fast as they have in the past. High-frequency beam technology in 5G will be radically new and will be able to meet future demand. At the same time, however, it will create massive mobile backhaul demand. The outcome is likely to shake the industry, leading not only to a new balance of power between mobile-only and integrated/fixed-line operators, but also to new potential revenue growth for the first time in many years.

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