



# Global Mobile Radar

May 2017



## About the GSMA

The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with almost 300 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai, Mobile World Congress Americas and the Mobile 360 Series of conferences.

The Global Mobile Radar series focuses on potential drivers of innovation and disruption across the digital economy. These reports highlight potential scenarios and examine the implications of these disruptions for a range of industry players, including the mobile operators. The reports are intended to be the basis for discussion and do not represent official GSMA positions on these future developments.

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# New disruptions on the Global Mobile Radar for Q2 2017

The pace of change in the digital ecosystem remains rapid, especially in mature sectors long thought to hold high barriers to disruption. The convergence of media, networks and content continues apace as well. In this edition of the Global Mobile Radar we look at three sectors where digital technologies are changing the nature of products, services and value chains.

In part two of our look at the video sector, we move on from content formats to dive into market structure, asking whether over-the-top players are changing the rules of the game. But could the disruptors become the disrupted, with the rise of 'super aggregators' threatening to change forever how content is distributed and the business models from which it is monetised?

We also look at the satellite industry, a sector that has faced decades of financial challenges, but where a new breed of player is emerging. Will the growth of constellations, such as those proposed by OneWeb, SpaceX and others, provide a complement or threat to established terrestrial connectivity networks?

There's a deep dive into augmented and virtual reality, where technological progress is bringing a long-held vision closer to mass adoption. With major platforms and handset manufacturers committed to a virtual future, it is perhaps only content that lags behind in the promise of a fully immersive experience.

Finally, our infographics chapter looks at the market for 3D and 4D printing. The technology promises to rewrite the value chain for manufacturing; we ask whether 3D printing could lead to the migration of value from hardware to software and the emergence of new distribution platforms.

We trust that the topics featured in this edition of the Global Mobile Radar spark plenty of debate within your organisations and help you take actions now for the future ahead.

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# 2

## Key takeaways





# Disruption of the video ecosystem

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- Advances in technology and the digital ecosystem are transforming the nature of video content. These same forces are disrupting the television industry (the 'traditional video ecosystem'), with the emergence of a new online video ecosystem.
  - The near ubiquity of broadband access has reduced the marginal cost of content distribution to zero, disrupting the traditional video ecosystem's business model of aggregating distribution and content. New digital players have emerged and scaled rapidly, with revenues and value now following audiences online.
  - Both the traditional and online video ecosystems are competing for the same thing (eyeballs), monetised by the same revenue models (advertising or subscription). Content is a key differentiator in both cases. The growth of the online medium is therefore likely to lead to an accelerated rate of disruption in the traditional video ecosystem.
  - The role of super aggregators is likely to grow in importance, as customers will need services and platforms that make discovering and accessing the growing array of content easy and manageable. Key questions remain, such as whether these platforms will be open or closed, software or hardware based.
  - Major internet platforms are increasingly launching their own streaming channels. Such moves could allow them to adopt the pivotal role of super aggregators, gaining further scale and competitive advantage from the integration of social sharing and online video content.
  - The role of the telecoms operator in this evolving landscape is uncertain. However, as consumers increasingly demand the ability to view content any time and any place, the value of offering authenticated access to content on a range of devices and across a range of network accesses may prove attractive to content creators and distributors.
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# AR/VR: a reality check

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- Virtual and augmented reality have been the focus of much hype and speculation in recent years. Most early AR/VR concepts, and certainly the bulk of recent launches and hype, have focussed on the consumer space, but enterprise use cases are becoming compelling.
  - One of the most heavily anticipated applications is in the creation of new consumer entertainment experiences, such as live streaming of a concert or sporting event to a user at home, while the combination of AR/VR with other emerging technologies such as IoT and 3D printing may provide the highest value opportunity.
  - The technology and market are still in their infancy; there are a number of issues to overcome that will determine whether VR/AR can fulfil its potential and reach widescale adoption. These revolve around hardware and technical issues, the need for improved realism, and a lack of dedicated AR/VR content.
  - Industry giants such as Apple, Google, Microsoft and Qualcomm are staking their claim in the market, while Facebook is aiming to create a new communication platform that is "part of daily life for billions of people". The reality though is likely to be less hyperbolic. AR/VR will more likely form an extension to the mobile ecosystem as a means of accessing content rather than a platform in itself, leveraging the billions of smartphones already in circulation.
  - Although the immediate battleground is around the devices and headsets themselves, commoditisation of hardware will lead to a shift to content becoming the primary revenue driver. Specialised AR/VR content will be key in the development and widescale adoption of the technology – and those who create, distribute and own the rights to it will be best placed to take advantage of the exponential growth the AR/VR market promises.
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## Satellites and star wars

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- The last six months have seen a wave of announcements and deals in the satellite communications market. Two privately funded companies – SpaceX and OneWeb – are the principal actors but there is a growing tail of others from pure-play operators such as O3b Networks to aerospace conglomerates such as Boeing and EADS.
  - Deployment plans follow a so-called 'constellation approach', which differs from previous ill-fated satellite efforts by using lower altitude orbital slots and much larger volumes to maximise ground area coverage.
  - The increased density of LEO satellite constellations being proposed is made possible by significant cost reductions at all levels of the supply and production chain, including lower component costs, smaller form factors (enabling more satellites to be launched on a single rocket) and the use of robotics in manufacturing. Vertical integration also helps SpaceX.
  - The most tangible opportunity for LEO satellites is in rural internet access; we forecast mobile internet penetration to rise from 48% to 60% of the global population between 2016 and 2020, meaning 3.1 billion people will still be without access.
  - Satellite as an end-to-end direct-to-consumer option for serving the unconnected has generated media speculation and grand visions of 'reinventing the internet in space' but technical and regulatory obstacles will make this difficult. The more viable and likely scenario is for satellite operators to sell connectivity on a wholesale basis to the mobile operators, which would acquire and manage the end customer relationship.
  - This would complement existing network expansion efforts among mobile operators and, ceteris paribus, should provide an accelerating impact to overall mobile internet take-up from 2020.
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## 3D printing: from prototype to product

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- 3D printing has been in development since the mid-1980s but activity has accelerated over the last 12-18 months. Manufacturing-dependent sectors such as automotive are the earliest adopters.
  - Take-up is now expanding (in some cases rapidly) into medical devices, dentistry, defence and aerospace, and architecture. This has been driven by lowering costs and use of technologies that allow a wider range of materials to be printed.
  - 3D printing has potential to fundamentally change the cost structure of manufacturing and design intensive industries such as automotive. Current activity is still mostly focused on building prototypes for product design. As acceptance grows, we expect a shift to market-ready products.
  - A forecast of forecasts suggests a market size of \$15-20 billion by 2018, 3-4x that of 2015. 4D is still nascent, and even by 2020 is unlikely to be more than 5% of the total. The long-term 3D and 4D printing story is much more about cost savings from reduced bill of material costs and less labour-intensive manufacturing. We would expect cost savings to be multiples of the \$20 billion revenue figure.
  - As printer costs fall and the savings to manufacturing processes crystallise, value will increasingly shift to the software layer. Industry structure is likely to consolidate at both the hardware and software levels. An open question is whether consolidation becomes full stack where winners control hardware and software, or whether value mostly sits at the software level (hardware commoditised) with ecosystems formed around a select group of platforms.
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# 3

## Disruption of the video ecosystem



The previous edition of the Global Mobile Radar<sup>1</sup> examined the fundamental paradigm shift in the nature of video content – from highly scripted content with a linear run time to increasing amounts of user-generated video, including live video feeds and curated collections of video clips. The report also looked at the future implications of new developments such as immersive video and artificial intelligence capabilities.

Here we examine the changing landscape for video consumption and distribution (most simply referred to as television), looking at how these changes in the nature of content and broader technological developments have disrupted the television and broadcasting industries and allowed the emergence of new players. The digital revolution has been a long time coming, but we may now be approaching a significant inflexion point as new ecosystems emerge and eyeballs and revenues shift rapidly online to new OTT players.

## 3.1 Executive summary

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Advances in technology and the digital ecosystem are transforming the nature of video content. These same forces are disrupting the television industry (the ‘traditional video ecosystem’). The value chain for television has already been disrupted once with the move from free to air to pay TV. It is now experiencing more fundamental disruption from the emergence of a new online video ecosystem.

The near ubiquity of broadband access has reduced the marginal cost of content distribution to zero, disrupting the traditional video ecosystem’s business model of aggregating distribution and content. New digital players (OTT players) have emerged and scaled rapidly, with a focus on bundling content acquisition with customer management. Revenues and value are now following audiences online and to non-linear formats, leading to a virtuous cycle as the availability of the best content online fuels further subscriber growth and funds more content production.

There is a generational element to this debate, as the overall pay-TV subscriber base in many western markets has remained relatively robust to date even as competition has increased. However, both the traditional and online video ecosystems are competing for the same thing (eyeballs), monetised by the same revenue models (advertising or subscription). Content is a key differentiator in both cases. The growth of the online medium is therefore likely to lead to an accelerated rate of disruption in the traditional video ecosystem. A potential tipping point looms on the horizon as digital advertising revenues are soon set to exceed those of traditional broadcasting media.

The role of super aggregators is likely to grow in importance, as customers will need services and platforms that make discovering and accessing the growing array of content (provided by multiple streaming platforms) easy and manageable. A number of key questions remain, such as whether these platforms will be open or closed, software or hardware based.

A further factor is the evolving role of the internet giants such as Google and Facebook. Facebook has already confirmed the launch of an app that would allow users to watch Facebook videos on TV as well as the live streaming of football matches, while Google is launching its own streaming bundle of channels under the YouTube umbrella. Such moves could allow the internet players to adopt the pivotal role of super aggregators, gaining further scale and competitive advantage from the integration of social sharing and online video content.

The role of the telecoms operator in this evolving landscape is uncertain, with the biggest take-away being that there is no single route to success. Infrastructure-based distribution no longer offers the guaranteed route to competitive advantage that it once did. However, as consumers increasingly demand the ability to view content any time and any place, the value of offering authenticated access to content on a range of devices and across a range of network accesses may prove attractive to content creators and distributors.

The next iteration of video content will involve more immersive user experiences, such as 360-degree video and ‘true’ virtual reality. There are still fundamental questions about which kinds of VR content will start to emerge, and in particular the dividing lines between what games companies and more traditional content providers will be looking to create. VR may be best suited to experiences, such as gaming and live sports/ events. In this scenario, if the VR headset does not replace the TV screen but rather complements it for specific experiences, then VR itself is unlikely to prove a significant disruptor to the existing video ecosystems.

## 3.2 The shifting value chain: distribution now free, new aggregators emerging

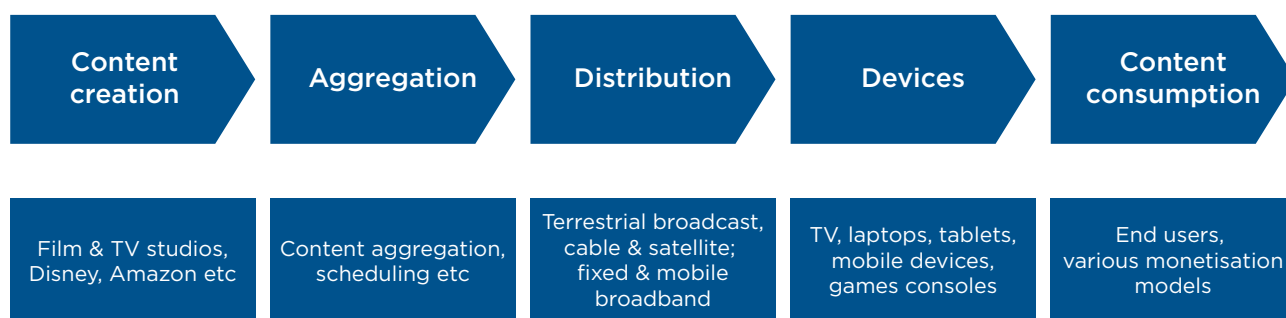
The free-to-air and pay-to-view versions of the traditional broadcasting industry followed broadly similar models. While content rights and production have typically taken the largest share of value, the roles of content aggregation and distribution were key elements in the value chain and controlled by the broadcasters.

Physical ownership (of for example cable networks) or regulatory constraints (licensing rights for terrestrial or satellite broadcasting) meant that distribution required significant capital investment but also created a quasi-monopoly for the owners of the distribution infrastructure. These companies then integrated distribution with content aggregation, with monetisation through either subscription revenues or advertising.

The most significant disruption of the value chain has come from technological developments: namely, the widespread deployment of broadband internet access (both fixed and mobile), combined with connected devices (tablets, phones, smart TVs and set-top boxes) and the necessary enabling software. These developments – the emergence of a streaming network topology – have allowed high-quality video content to be delivered to consumers any time and any place, effectively making distribution free to the marginal user.

Source: GSMA Intelligence

### 1 Broadcast and content value chain



Not only has distribution become almost free, but the new OTT players have allowed the rapid development of non-linear viewing. Consumers are able to view content when and where they want, rather than being bound by broadcaster scheduling or using recording devices. Content has effectively become atomised, consumed as individual units and no longer tied to broadcasting schedules. The popularity of this model has fed increasing demand for new serialised content, demand that is being readily met by the likes of Netflix and Amazon, with a number of OTT players now

choosing to make entire series of a show available for immediate download.

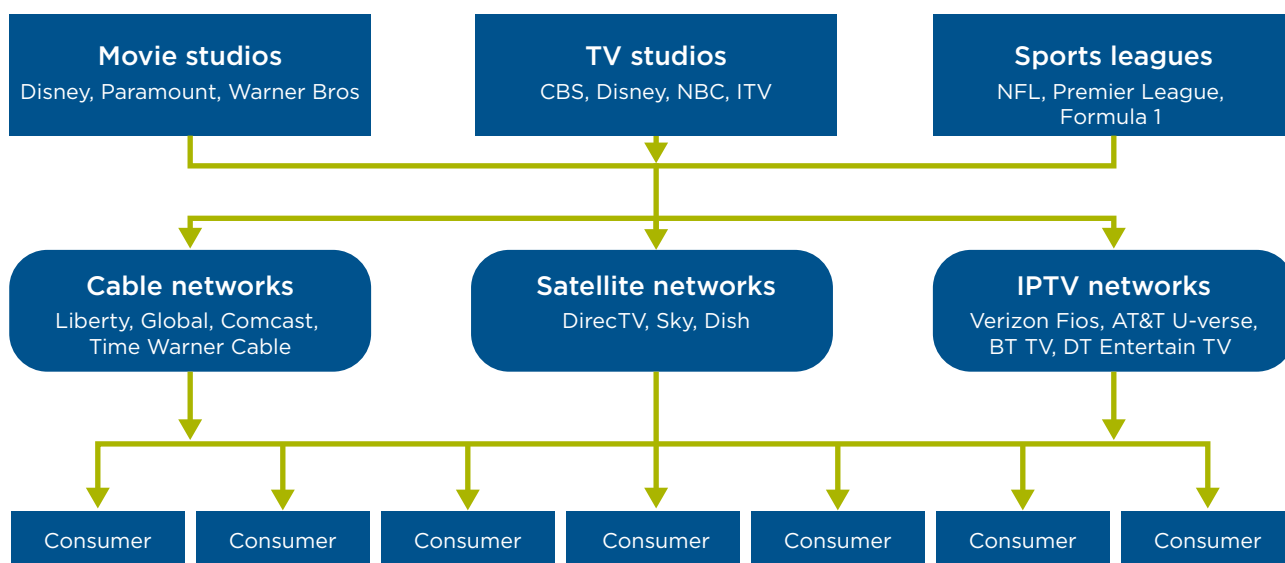
At the same time, new, cheaper models of content creation have emerged. For example, the most successful YouTube channels can attract audiences of several million but with limited production costs, ranging from effectively zero for the teenager video-blogging from their bedroom or sharing video clips of a pet, to less than \$50,000 for the more 'professional' channels.

## New online video ecosystem emerging, boundaries with social media blurring

There are now two parallel ecosystems for the creation and distribution of video content. The first is the traditional video ecosystem which encompasses traditional free-to-air and pay-TV providers, the latter including cable, satellite and telecoms operators. The second is the new online video ecosystem, which has a growing number of players and several different revenue models.

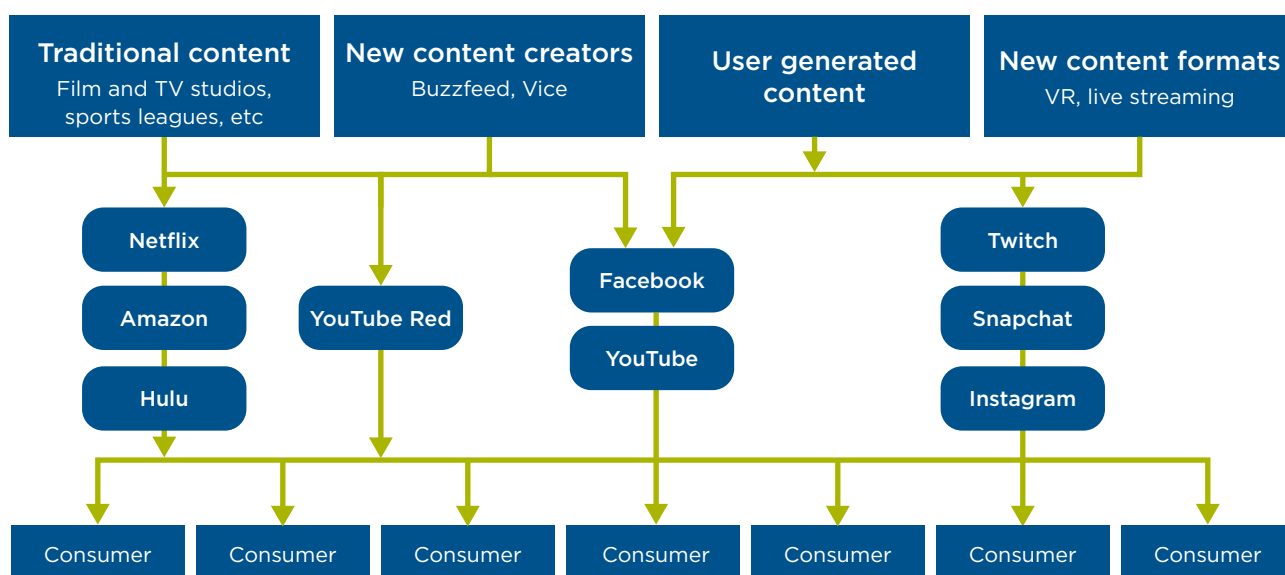
Source: GSMA Intelligence

### 2 Traditional video ecosystem



Source: GSMA Intelligence

### 3 Online video ecosystem



The new online video companies typically adopt one of three business models: advertising supported video on-demand (AVOD); transaction-based video on-demand (TVOD), or subscription-based video on-demand (SVOD). Table 1 shows a number of the leading online video and streaming companies from across the world.



Source: Company data

## 1 Selected online video companies

| Company                              | Geography   | Business model                  |
|--------------------------------------|---|---------------------------------|
| Netflix                              | Around 200 countries  | Subscription video              |
| Hulu                                 | US only   | Subscription video, advertising |
| Amazon Prime Video                   | Around 200 countries  | Subscription video, transaction |
| HBO Now                              | Limited outside the US  | Subscription video              |
| Viu (PCCW Media)                     | Asia focus: around a dozen markets  | Subscription video, advertising |
| Hooq                                 | Asia focus: including the Philippines, Thailand, India and Indonesia              | Subscription video, advertising |
| Iflix                                | Asia focus: including Pakistan, the Philippines, Thailand, Malaysia and Indonesia | Subscription video              |
| Iqiyi, LeTV, Youku Tudou and Tencent | China   | Subscription video              |

As the online video ecosystem starts to mature, there is increasing crossover between the traditional and new ecosystems. Many traditional broadcasters and content owners from across the world, ranging from HBO to the BBC, are now distributing their content through OTT video platforms.

### 3.3 Competition between traditional and online ecosystems

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Having highlighted the rise of the new online video ecosystem, we now examine to what extent these new players are competing with those in the traditional ecosystem. Television in the past fulfilled multiple roles in people's lives,<sup>2</sup> beyond simply being an entertainment medium. The five key roles included keeping people informed; providing education; viewing of live sports events; story telling; and escapism.

The first two of these activities have already been digitised, with many people now using the internet and digital media for news and educational content. Escapism has also now been digitised by online social media, or more particularly by one major player, Facebook (although challengers such as Snapchat are growing rapidly). OTT video companies such as Netflix are now doing an effective job of digitising the fourth role, around story telling.

As a result, players and services in the new video ecosystem are not necessarily direct competitors for the services in the traditional broadcast ecosystem. For example, watching a film on Netflix may replace a cinema trip rather than two hours of traditional linear TV viewing. Similarly, a teenager watching live video games on Twitch may then spend less time on their games console.

However, there is an overriding reality that ultimately the traditional and online video ecosystems are competing for the same thing (eyeballs), monetised by the same revenue models (advertising or subscription). Content is a key differentiator in both cases. Both eyeballs and advertising spend are ultimately fixed, even if for example the total time spent viewing video content grows as tablets and mobiles allow viewing on the move.

Facebook has for several years been clear on its desire to capture a growing share of TV advertising spend, with revenues steadily following eyeballs online and away from traditional media. PWC has estimated that 2017 will see an important tipping point, as total digital advertising revenues in the US for the first time exceed those on television and the traditional broadcasters.<sup>3</sup>



<sup>2</sup> "The Great Unbundling", Stratechery, January 2017

<sup>3</sup> "Digital Ad Spending Will Surpass TV Spending For The First Time In U.S.", Forbes, September 2016

### 3.4 The drivers of OTT growth: the rise of the ‘nevers’ and ‘cutters’

The growth of video streaming has drawn two key responses: consumers are increasingly responding by dropping pay-TV subscriptions (the ‘cutters’), while traditional broadcasters are reacting to this threat by offering more affordable (‘skinnier’) bundles. As a result, pay-TV ARPU levels in the US (which were high by global standards) are now under pressure, while the virtuous upselling cycle to digital and ever larger packages that has driven European cable over recent years could also now be under threat.

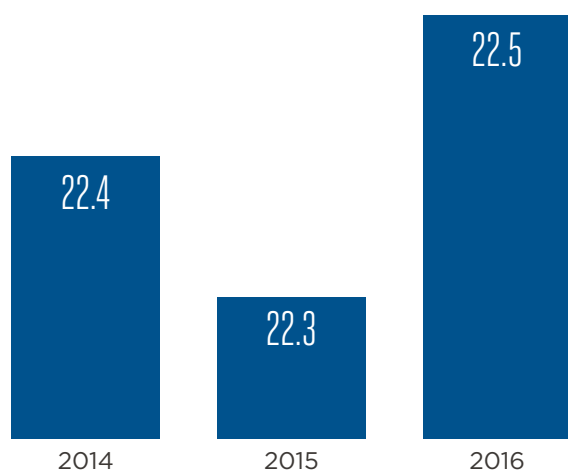
The pay-TV subscriber base in markets such as the US has remained remarkably resilient to date, though there has been a shift in the mix across platforms. Large cable operators such as Comcast have seen a broadly stable subscriber base. AT&T is now de-emphasising its U-verse IPTV offer in favour of pushing its DirecTV service, based on the acquisition

of the latter’s satellite TV operations in 2015, but has seen its overall pay-TV base remain stable. Market data suggests that in aggregate the US pay-TV industry base (excluding the OTT players) stood at around 94 million at the end of 2016, and had lost around 1 million subscribers over the previous year.

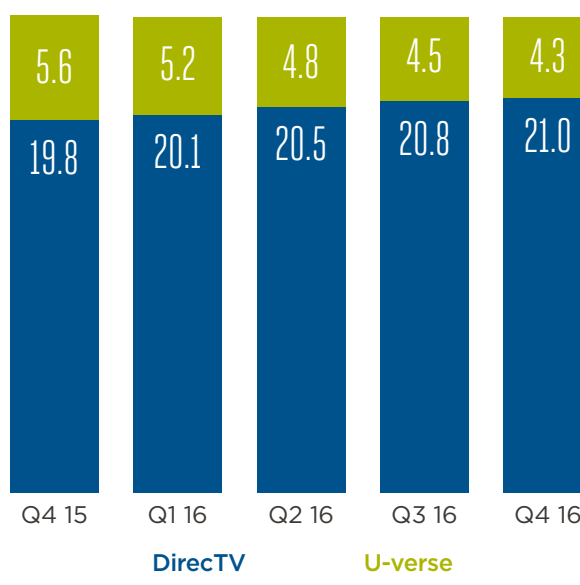
Source: Company data

#### 4 Video subscriber bases in US

Comcast video subscribers (millions)



AT&T video subscribers (millions)



That momentum may be starting to change. A recent study found an astonishing 41% of US adults said they would be shaving – or cutting – the pay-TV cord in the next 12 months.<sup>4</sup> Other forecasts have suggested that the pay-TV component of the traditional video ecosystem in the US could lose 10 million subscribers by 2022.<sup>5</sup>

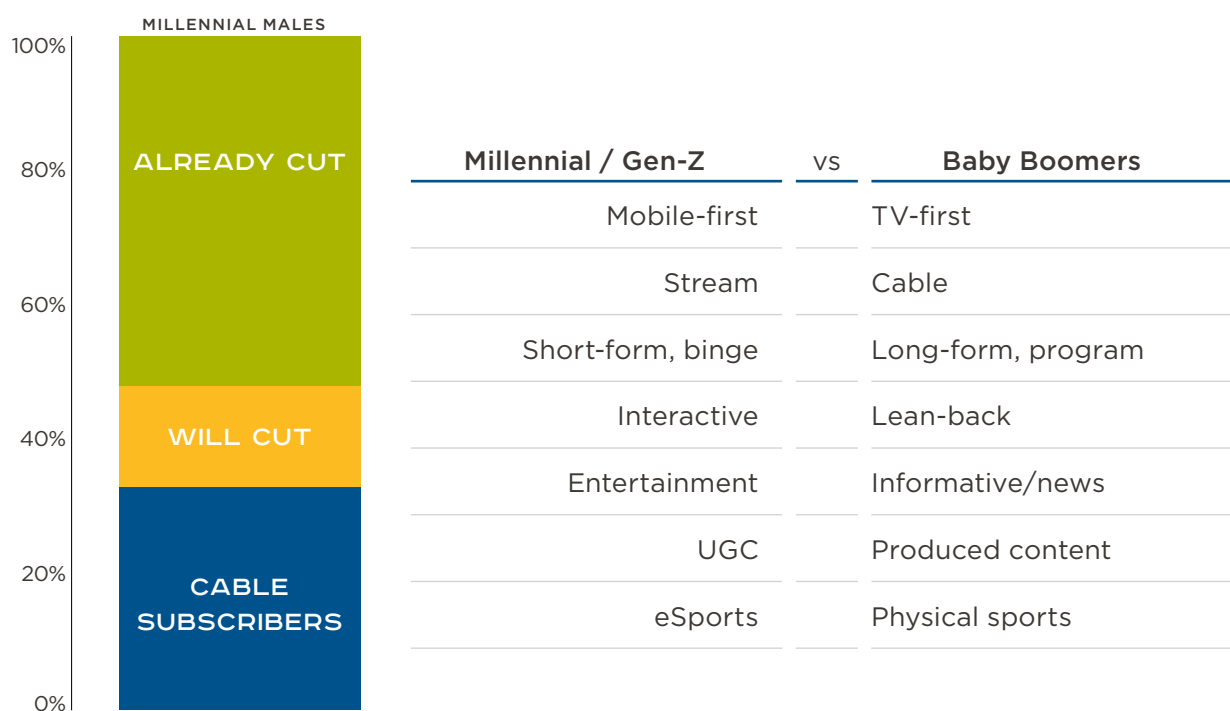
The growth of online streaming is set to continue. Estimates suggest that on-demand viewership will soon exceed linear viewing. Non-linear viewing is estimated to be around 20% of total viewership in the US, a figure that is forecast to double by 2018.<sup>6</sup> The question is then whether the growth of non-linear

viewing translates directly into an acceleration of cord cutting. Total content viewership will likely grow, but the ongoing shift to new online players will inevitably erode viewership for the traditional video ecosystem.

There is also a demographic aspect to this, with the younger generations (the millennials) already accustomed to viewing content where they want and when they want, namely online content viewed on tablets and mobile devices. This is the rise of the ‘nevers’ – a generation unlikely to subscribe to a traditional pay-TV service (or indeed view linear TV from a free-to-air service).

Source: Cracking the Digital Habits of the Elusive Millennial Male, Videology 2017

## 5 Digital habits of millennial males



For OTT providers, there are signs of an emerging virtuous cycle; growing user bases drawn from both the nevers and the cutters will drive scale for the new online platforms, providing the revenues to add more content (as well as data to improve analytics) and so further grow the subscriber base. Netflix is the leading example of this cycle, with the company set to carry more than 1,000 hours of original content in 2017, compared to around 600 in 2016. Data from the company highlights how original programming appears to be highly correlated with user engagement (or viewing time spent per subscriber).

4 Global Video Index Q3 2016 Ooyala

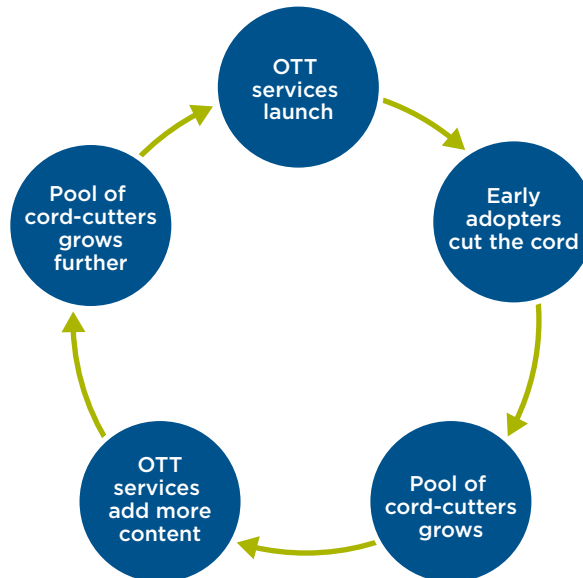
5 "Decline in North American pay-TV subs", Broadband TV News, March 2017

6 "The Digital Revolution Is Disrupting the TV Industry", BCG Perspectives



Source: Credit Suisse

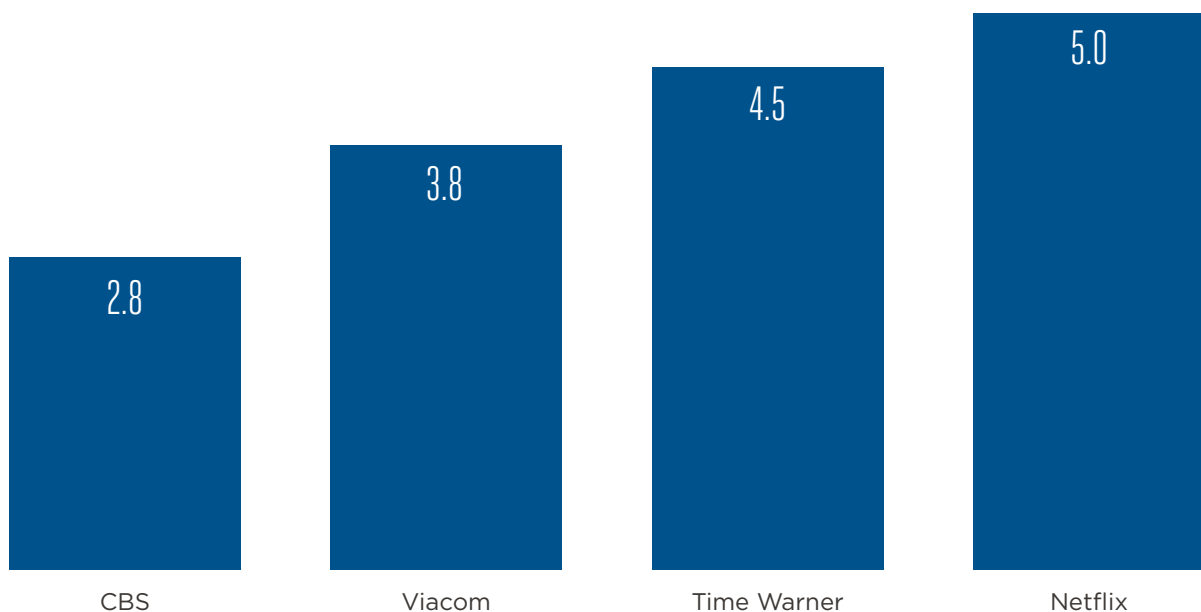
## 6 Virtuous cycle as cord cutting sucks in the best content



As a result of this virtuous cycle, Netflix has a content production budget that exceeds that of many players from the traditional video ecosystem. The move to invest in proprietary content is being followed by other online providers, including Hulu and Amazon. Amazon stated that it would double its content spend in the second half of 2016 compared to the first half, suggesting an annual run rate of around \$3 billion.

Source: Company data

## 7 Content production budgets (\$ billion)



## 3.5 Strategic options for the traditional video ecosystem players

There are a number of different options for the traditional ecosystem players facing the challenge of the new OTT players. Several of the traditional players have reacted by offering their own 'skinny' bundles, smaller channel bundles delivered by their own online streaming services. Examples include Sling and DirecTV Now in the US, Now TV in the UK and TVer in Japan.

These offers generate lower revenues and margins than the bigger bundles but by developing a direct-to-consumer model, broadcasters aim to develop closer customer relationships, access new customer segments and gain valuable data on viewing habits. In some cases, ownership of broadband infrastructure has been a positive, with Comcast for example offering free data usage for consumers viewing its Comcast streaming packages.

At a strategic level, traditional broadcasters and content companies have reacted in different ways to the impact of digital disruption. Some have vertically integrated into content production, mirroring the move by some of the digital players. Others have looked to consolidation, at both ends of the value chain (in content creation and distribution) with broadcasters looking to achieve scale in the fight against the OTT players.

Source: Adapted from Accenture: The Future of Broadcasting Issue III

### 1 Comparison of player strategies

| Player                        | Strategy   | Company examples                   |
|-------------------------------|--|------------------------------------|
| Incumbent digital operators   | Become leading one-stop platform for content providers and consumers alike; extend online and mobile platforms | Sky, Virgin Media, Canal+, DirecTV |
| Challenger digital operators  | Develop new platforms based on better customer propositions and services for third parties                     | Verizon, BT, Telstra               |
| Traditional content providers | Protect existing business while exploring new opportunities e.g. own streaming offers                          | Disney, HBO, ITV                   |
| Digital OTT providers         | Scale rapidly, enhance customer proposition. Upstream expansion into content production                        | Netflix, Hulu, Amazon              |

AT&T's planned acquisition of Time Warner can be seen both as an example of the desire to realise scale and a move towards vertical integration (integrating content production with distribution). Following the acquisition of DirecTV, AT&T is already the largest pay-TV company in the US. The acquisition of Time Warner would give the company greater scale in distribution but also crucially a large content library.

Some of the anti-trust concerns raised around these consolidation deals by network operators centre on whether increased control of broadband and satellite distribution networks would allow a company to discriminate against OTT providers. In that sense, these emerging scale players are waging a bigger battle for the "primary customer relationship" in distributing video. In order to command customers' loyalty and attention, premium content could in future be a valuable weapon in that fight.

## 3.6 Future outlook: the rise of the super aggregator



**Will the future hold a landscape of infinitely fragmented, disaggregated content sources where consumers subscribe to each channel, service or app individually or will consolidation and aggregation win out with the emergence of a new breed of global “super aggregator”?**

Will We See The Rise Of The Content “Super Aggregators”?  
Paul Stathacopoulos, LinkedIn, June 2015

Given recent moves towards consolidation and vertical integration outlined in the previous section, it is likely that the industry has already moved beyond the period of peak fragmentation. Going forward, the role of super aggregators is likely to become more important, as customers will continue to need platforms and services that make discovering and accessing content easy and manageable, particularly as the variety of content continues to grow. This raises a number of questions around what type of platforms these will be:

- **Open or closed?** An open platform would allow third-party content and service providers to establish direct relationships with customers. In a closed platform, the platform owner controls all interactions with the end customer.
- **Physical or software based?** Physical platforms such as the set-top box that are a common feature of pay-TV subscriptions are already evolving to offer a broader range of apps and services beyond the core channel bundle (provided today by European and US cable operators). Software platforms are gaining traction as the preferred route for the OTT providers such as Netflix, as well as new streaming services from traditional players such as DirecTV Now.

### Where does social media sit?

Facebook has already confirmed the launch of an app that would allow users to watch Facebook videos on TV, as well as a deal to live stream some Mexican football matches. Google is reported to be in discussions aimed at launching its own streaming bundle of channels under the YouTube umbrella (having already reached agreement with the likes of CBS to carry some of its programming).<sup>7</sup>

In this scenario, the likes of Google and Facebook could emerge as the true super aggregators, using their open platforms to distribute both their own and third-party content. Just as Amazon has emerged as the true giant of online retail, so Google and Facebook could dominate the aggregation, distribution and even production of video content.

7 “CBS signs on for Google streaming service — and more networks are expected to follow”, Los Angeles Times, October 2016

These companies could then offer global distribution and the advantages of centralised billing and supporting cloud infrastructure on a global basis. Such platforms would have even greater appeal to advertisers, and prove attractive to content owners looking to maximise their audiences and revenues. This could further undermine the traditional broadcasting model (as both viewers and advertisers migrate online), leading to further consolidation among the remaining players (traditional broadcasters and digital natives alike).

The role of the telecoms operator in this evolving landscape is uncertain, with the biggest take-away that there is no single route to success. Infrastructure-based distribution no longer offers the guaranteed route to competitive advantage that it once did.

However, as consumers increasingly demand the ability to view content any time and any place, the value of offering authenticated access to content on a range of devices and across a range of network accesses may prove attractive to content creators and distributors.

Some operators with deeper pockets are taking this multi-network, multi-platform approach a step further through vertical integration into content ownership. Given the increasing value and revenues accruing to content ownership, there is some strategic logic to these moves, even if regulatory considerations (for now at least) are likely to limit the extent to which operators are able to extract synergies with their distribution networks or restrict access to proprietary content.

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## VR and further content evolutions

The next iteration of video content will involve more immersive user experiences, such as 360-degree video and 'true' virtual reality, which is typically computer rendered. While VR has been slow to gain traction, there are now a growing range of devices available in the market. It remains unclear though to what extent VR will be a significant category for the video ecosystem, and how disruptive it could be. The current landscape and outlook for VR is discussed in detail in the next section of this edition of the Global Mobile Radar.

With the consumer use case for VR currently focusing on gaming and its use in broadcasting still at an embryonic stage, there are fundamental questions to answer about which kinds of content will start to emerge, and in particular the dividing lines between what games companies and entertainment specialists will be looking to create. Both the traditional and online video ecosystems are best at 'storytelling'; VR may be best suited to 'experiences'. Viewing fatigue may be a key factor when watching content in VR, a challenge that may count against it for use in long-form storytelling, as well as the increase in production costs VR would entail.

As well as gaming, the range of experiences for VR could include live sports and events, particularly those that benefit from bringing the viewer closer to the action. This would be good news for sports and music rights owners, opening the door to a new range of VR ticketing options to place a customer on stage at a concert or behind the goal at a football match. The National Basketball Association (NBA) has already announced that it is broadcasting one game per week in the current season in VR (accessed via the Samsung Gear headset).

In this scenario of VR focusing on experiences, the VR headset does not replace the TV screen (or tablet/mobile screen) but rather complements it for specific experiences. VR itself is thus unlikely to prove a significant disruptor to the existing video ecosystems.



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AR/VR: a reality check

## 4.1 Executive summary

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Virtual reality (VR, simulated real-life environments) and augmented reality (AR, overlaid digital content) have been the focus of much hype and speculation in recent years, and use cases are becoming much more tangible.

Most early AR/VR concepts, and certainly the bulk of recent launches and hype, have focussed on the consumer space (particularly gaming and entertainment), primarily due to the availability of the technology. Pokémon Go for example became the fastest mobile game in history to surpass \$1 billion in worldwide gross revenues, and elsewhere, various Internet players (e.g. YouTube and Facebook) and major media corporations (e.g. Sky and Disney) have started to explore the viability of VR content. Meanwhile, enterprise use cases are becoming compelling in several verticals such as commerce, design, construction, remote maintenance, transportation, healthcare and military.

One of the most heavily anticipated applications for AR/VR is in the creation of new consumer entertainment experiences, such as live streaming of a concert or sporting event to a user at home. In addition, combining AR/VR with other emerging technologies such as IoT and 3D printing may provide the most interesting use cases and the highest value.

However, the technology and market are still in their infancy; there are a number of issues to overcome that will determine whether VR/AR can fulfil its potential and reach widescale adoption. These issues can be grouped into three categories:

- hardware and technical issues, including cost, ergonomics, computer vision and bandwidth
- realism, specifically the need for improved image and sound quality, and advancements in motion tracking and latency
- lack of dedicated AR/VR content and challenges around content aggregation.

If these are overcome, what does the future of AR/VR look like? Industry giants such as Apple, Google, Microsoft and Qualcomm are expecting big things and are increasingly staking their claim in the market, while Facebook, having acquired Oculus VR, is aiming to create a new communication platform that is “part of daily life for billions of people”. However, with some recent setbacks including the discontinuation of Google Glass and a lukewarm reception to the launch of the latest Oculus Rift headset, the reality is likely to be less hyperbolic. Given their price tags, dedicated AR/VR headsets such as the Oculus Rift and HTC Vive will only really appeal to tech enthusiasts, leaving mobile-based solutions (such as Samsung’s Gear VR) as the dominant form-factor for the majority of applications. AR/VR will therefore more likely form an extension to the mobile ecosystem as a means of accessing content rather than a platform in itself, leveraging the billions of smartphones already in circulation.

This is not to say that the opportunity is limited. Although the immediate battleground is around the devices and headsets themselves, commoditisation of hardware will lead to a shift to content becoming the primary revenue driver. Specialised AR/VR content will be key in the development and widescale adoption of the technology – and those who create, distribute and own the rights to it will be best placed to take advantage of the exponential growth the AR/VR market promises.

## 4.2 Landscape and evolving use cases

### The AR/VR landscape

AR and VR have a similar goal of enabling a user to interact with computer-generated elements, but they aim to achieve this in different ways and with different levels of immersion.

#### Augmented and mixed reality (AR and MR): see the world differently

Computer-generated content added on top of the real world, allowing users to interact with virtual objects while remaining in touch with their surroundings. AR consists of digital pop-ups or notifications overlaid on a view of the real world as seen through a smartphone or tablet (e.g. Pokémon Go).

MR is an extension of this, with 3D digital elements added to real-life objects with realistic rotation, perspective, colour, shading and occlusion, allowing interaction and manipulation via a headset and (in some use cases) gloves (e.g. Microsoft HoloLens and




Magic Leap). In some early MR concepts, users will be able to switch between overlaid digital objects and full immersion by adjusting the transparency of the screen.

#### Virtual reality (VR): see a different world

Computer-generated simulation of a real-life environment, with users isolated from the real world and fully immersed in an artificial reality. Users can see, hear, touch and (possibly) smell objects arranged in an artificial world, with interaction usually through a headset and sometimes gloves (e.g. Google Cardboard, HTC Vive, Oculus Rift, Samsung Gear and Sony PlayStation VR).

Source: GSMA Intelligence

### 1 Different approaches to digital interaction

|                                  | Real world ← → Digital world  |  |   |
|----------------------------------|---|--|---|
|                                  |  |  |  |
|                                  | Augmented Reality   | Mixed Reality  | Virtual Reality   |
| Full immersion                   | No  | Mixed  | Yes   |
| Interaction with real world      | Yes   | Yes  | No  |
| Manipulation of digital elements | No  | Yes  | Yes   |

The current AR/VR ecosystem is broad and far reaching, covering hardware, software and distribution. Most major tech and internet players have at least some interest or stake in AR/VR technologies or content, and numerous start-ups (CB Insights currently tracks 111) are fighting for their part in the potential platform of the future. These start-ups are attracting record levels of risk capital to the sector – over \$2 billion in 2016, more than the last three years combined.

Source: GSMA Intelligence

## 2 Example players in the AR/VR value chain



Despite the shared ecosystem and value chain, AR and VR are quite distinct. Both will continue to develop over the next few years with regards to realism and interaction, and could eventually converge to form the future vision of MR (Figure 3). However, for the near term they involve different companies developing different technologies with varying propositions.

Source: GSMA Intelligence

### 3 The future of AR/VR

|    | Now  | Near term<br>(3–5 years)  | Long term<br>(10+ years)   |
|----|--|---|--|
| AR | Rudimentary digital overlays, mostly accessed on a smartphone or tablet<br><br>e.g. Pokémon Go, Qualcomm AR  | Still basic overlays on a flat surface, but higher quality and more immersive/interactive<br><br>e.g. streaming AR services, accessed on the go | AR, MR and VR converge<br><br>Variable transparency depending on context and application, switching between modes at the touch of a button   |
| MR | Early prototypes of 3D elements combined with real-world objects, with interaction via a headset and gloves<br><br>e.g. Microsoft HoloLens, Magic Leap               | Computer-generated objects are more realistic and interactions are more intuitive   | Viewed through normal-looking glasses, sleek headsets or, ultimately, contact lenses. Entire scenes are so realistic and interactive that they are almost indistinguishable from reality |
| VR | Mostly three degrees of freedom (3DoF) and non-interactive content. Interaction via a headset and gloves<br><br>e.g. various VR games and pre-recorded video content | Ability to move around (6DoF) with better sense of reality and presence<br><br>e.g. live events (sports, concerts)                              |  |



## Use cases

Over the last year or so, the potential applications of AR and VR have received some major attention in the media and are becoming much more tangible. These use cases can mostly be divided into those targeted at consumers, and applications aimed at businesses and industry.



### Consumer applications

Most early AR/VR concepts, and certainly the bulk of the hype, have focussed on the consumer space, with the main use cases being gaming and entertainment. This is primarily due to the availability of the technology. AR/VR, while still developing, provides an interesting new angle to gaming and entertainment using the technology as it exists today, and is therefore where the short- to mid-term opportunity lies. Recent examples include the following:

AR-based Pokémon Go became the fastest mobile game in history to surpass \$1 billion in worldwide gross revenues, doing so after just over six months.<sup>1</sup> Most other gaming launches have been VR based, including Resident Evil 7: Biohazard and Batman: Arkham VR (PlayStation VR), and Eve: Valkyrie and Alien: Isolation (Oculus Rift and HTC Vive). Hundreds of developers are making VR games for launch in the near future.

With regards to entertainment, both YouTube and Facebook launched live 360-degree video streaming during

2016, and short-form VR content is emerging, including studio-backed VR mini-series (such as *Invisible*), documentaries (produced by RYOT) and sports clips. Major media corporations such as Sky and Disney are also exploring the viability of producing new VR content.

Other emerging applications are in education, such as simulated VR learning environments or using AR tools to support classroom-based teaching; and in travel, including virtual tourism, navigation aids and instant translation via digital overlays.

One of the most highly-anticipated applications of AR/VR is in the creation of new consumer entertainment experiences: for example, live streaming of a concert or sporting event to a user at home. In this vision, the user is fully immersed and can experience the event as if they were there in person, but can also interact in a completely natural way with their friends, who are present in the virtual world but are actually also at their own homes. One piece of recent innovative technology could play a big part here – Microsoft's Holoportation demonstrates high-quality, real-time 3D reconstructions and transmission of an entire space, including people and objects, allowing users wearing AR or VR displays to see, hear and interact with remote participants almost as if they were present in the same physical space.

1 "Pokémon GO Has Grossed \$1 Billion Worldwide Since Launch", Sensor Tower, January 2017



## Enterprise applications

Beyond the flash of consumer entertainment, enterprise use cases are becoming compelling in several verticals, such as commerce, design (industrial, architecture), construction, transportation, healthcare and military. Remote maintenance is a particular area of interest, for example in hazardous environments such as nuclear reactors or deep underwater. Examples include the following:

Fundamental VR has developed an integrated VR and haptic tool that is used in training surgeons to administer drugs during knee surgery. The system allows a safe, repeatable environment within which to refine infiltration technique, providing real-time feedback along with the feeling of tissue and bone structures.

BAE Systems is using a VR system developed by Virtualis in the planning and production of its next-generation submarines. By creating virtual 3D models of the entire vessel, the system replaces the need for physical models and allows for more flexibility in the manufacturing process itself.

Amec Foster Wheeler has partnered with VTT Technical Research Centre of Finland Ltd and Tampere

University of Technology to develop a remote handling system for ITER (International Thermonuclear Experimental Reactor), the world's largest fusion energy project. The system brings together high-tech robotics and VR platforms to assist in the maintenance of reactor components that cannot be approached by human operators.

Honeywell has developed VR technology for future DARPA and US Army ground vehicles which replaces glass windows with display technology that projects a wide-angle, high-definition view of external conditions. The system allows the operator to track optimal routes over difficult terrain, review infrared and terrain classification views, and see information on nearby allies and adversaries.

Despite these examples, there is still a long way to go before AR/VR technology is widely adopted in the enterprise space. This is largely due to the fact that enterprise solutions, certainly those in industrial applications, need to be the finished article and not reliant on technology that is still developing; there must be no issues with latency, bandwidth, user interaction and so on. This is exacerbated by vertical-specific applications, longer sales cycles, and the complexities of integration and compliance in workplaces. So while the biggest opportunity for AR, VR and, most compellingly, MR, will likely be in the enterprise space, this is a long-term vision that is unlikely to be realised for 5–10 years.

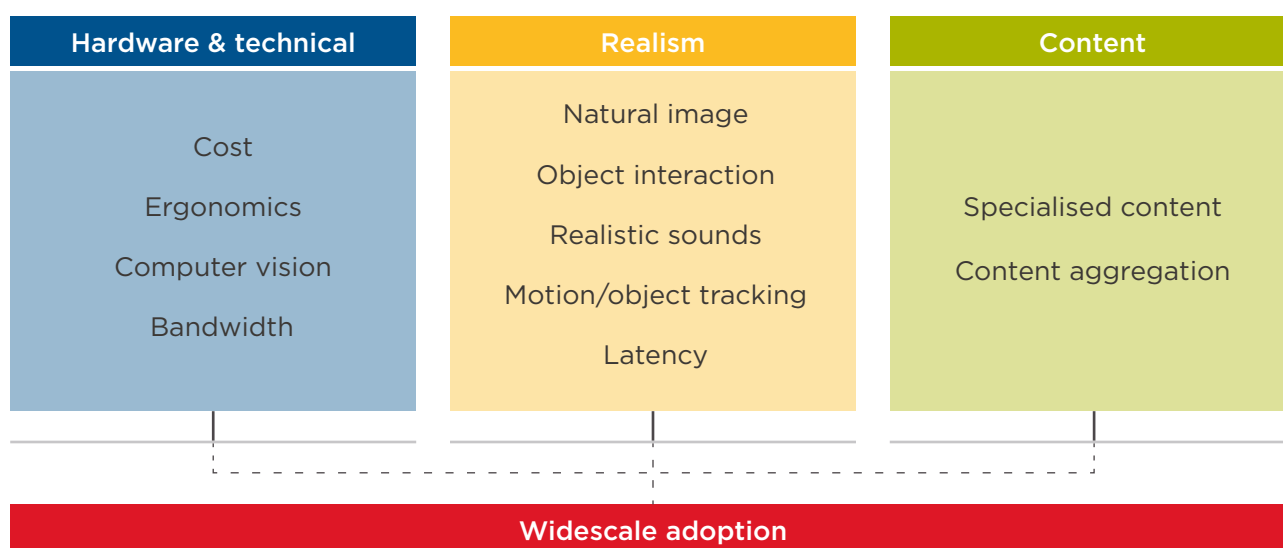
Over the next three to five years, it is the combination of AR/VR with other emerging technologies that may provide the most interesting use cases and the highest value. For example, in industrial IoT, AR/VR technologies can provide visualisation and analysis tools for the huge amounts of data collected across connected infrastructure. Similarly, the emerging field of 3D printing can be enhanced with the use of AR/VR designing, editing and visualisation tools for complex 3D structures where traditional tools (using a mouse and a 2D monitor) fall short.

## 4.3 Realising the potential of AR/VR

Good progress has been made in AR and VR in recent years, with advancements in imaging and display technology and with realistic concepts and use cases hitting the mainstream consciousness. The sector is, however, in its infancy, and there are a number of issues to deal with that will define whether this potential is realised and, importantly, the pace of adoption. These issues can be grouped into three categories: hardware and technical, realism, and content.

Source: GSMA Intelligence

### 4 Realising the potential of AR and VR



#### Hardware and technical

Hardware challenges are primarily an issue for VR/MR, as AR applications still largely use smartphones and tablets as the medium of consumption. Progress has been made in the economic scaling of VR technology, with the cost of hardware (headsets in particular) steadily declining. VR headsets that use smartphones as displays, such as Google Cardboard (\$15), Samsung Gear VR (\$80) and more recently Google Daydream (\$79), are the entry point for most consumers when it comes to VR. Dedicated VR/MR headsets such as the Oculus Rift, HTC Vive, PlayStation VR and Microsoft HoloLens deliver a significantly higher-quality and immersive experience – but at a price.

**Cost** is therefore a major barrier to mass adoption, as dedicated VR headsets are currently expensive and require tethering to an external computer for graphics processing. For example, the Oculus Rift and HTC Vive headsets cost \$500 and \$800 respectively, and require a connection to a high-spec computer. Oculus recently lowered the minimum recommended specs, but a PC costing over \$500 is still required, and the dedicated Oculus Touch controller for gesture tracking costs \$199. Similarly, the Sony PlayStation VR headset costs \$400 and is an add-on to the PS4 which retails at around \$250. Microsoft's HoloLens development kit costs \$3,000.

Headsets at these prices will only really appeal to tech enthusiasts. Price points will need to significantly decline if they are to reach critical mass. As with most tech industries, Moore's Law can be applied here, with expected performance doubling or the cost for the same performance halving every 18 months.

Additionally, many other companies and start-ups are developing their own headsets (Osterhout Design Group, Avegant, Impression Pi, ANTVR, Cmoar, Opto, FOVE) and controllers (STEM System, Control VR, Gloveone, iMotion). This could create the necessary competition to help drive prices down.

Source: Company websites

## 1 Comparing major VR headsets



|               | Gear VR    | Google Daydream | Oculus Rift               | HTC Vive                  | PlayStation VR |
|---------------|------------|-----------------|---------------------------|---------------------------|----------------|
| Launch date   | Nov 2015   | Nov 2016        | Mar 2016                  | Jun 2016                  | Oct 2016       |
| Price         | \$79       | \$79            | \$499                     | \$799                     | \$399          |
| Requirements  | Smartphone | Smartphone      | High spec PC <sup>2</sup> | High spec PC <sup>3</sup> | PS4            |
| Weight        | 318g       | 220g            | 470g                      | 566g                      | 610g           |
| Resolution    | -          | -               | 1080×1200×2               | 1080×1200×2               | 960×1080×2     |
| Field of view | -          | -               | 110°                      | 110°                      | 100°           |
| Refresh rate  | -          | -               | 90 Hz                     | 90 Hz                     | 120 Hz         |
| Latency       | -          | -               | 20–30ms <sup>4</sup>      | 22ms                      | 18ms           |

Note: Display statistics for smartphone-based headsets are dependent on model of smartphone used

Another issue is **ergonomics**. VR headsets are still fairly heavy and bulky, and need to be tethered to an external processing and power source. For VR to scale, the form factor needs to be reworked to be smaller and more comfortable, with smaller (and cheaper) sensors that do not sacrifice accuracy, and sufficient processing power and battery capabilities integrated onto the headset itself. Mobile processors are available now that can handle the job, but battery capabilities are still many years away.

For a fully interactive and intuitive AR solution, a fundamental component is **computer vision**, which refers to the automatic extraction, analysis and understanding of useful information from a single image or a sequence of images. The challenge lies in extracting information of a 3D scene from its

2D projections, and combining this with multiple databases about the location, people, objects, buildings and so on, in real time. Low-level image processing of basic shapes (corners, edges, contours) and motion estimation is already a reality. However, advancements in object/feature recognition and tracking, 3D scene modelling/reconstruction and the interpretation of this evolving information, potentially aided by machine learning techniques, are necessary to take AR solutions into the realms of 3D object interaction and MR.

Aside from the devices themselves, another key challenge is **bandwidth**. For AR as it exists today, current networks (both mobile and fixed) are largely capable of meeting the requirements of overlaying simple digital elements on top of a camera image.

<sup>2</sup> Minimum Intel Core i3 6100 or AMD FX 4350, NVidia GeForce GTX 960 or AMD Radeon RX 470, 8GB RAM

<sup>3</sup> Minimum Intel Core i5 4590 or AMD FX 8350, NVidia GeForce GTX 970 or AMD Radeon R9 290, 4GB RAM

<sup>4</sup> No official figures. Sub-20ms latency has been reported with use of Asynchronous Timewarp (ATW) technology

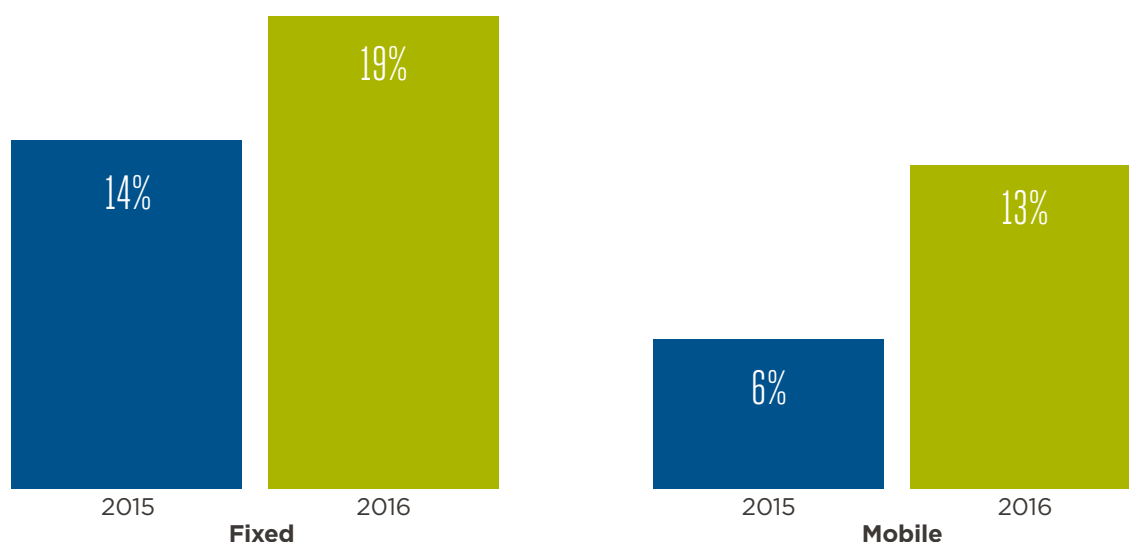
However, VR is far more demanding because of the simultaneous transmission of multiple images (one to each eye) at a high refresh rate – as much as 120 frames per second in the case of PlayStation VR compared to the 24 frames per second of ‘regular’ video. As such, bandwidth requirements of existing VR headsets are as much as 20 Mbps, similar to a 4K video stream.<sup>5</sup>

While this is not an issue with pre-recorded content transmitted from a PC or console, it becomes a challenge when pushing VR into the realms of live events and streaming services. Currently, only one in five countries across the world have average fixed

network speeds of over 20 Mbps, falling to one in eight for mobile networks. Similarly, fewer than 10% of connections to Akamai’s global CDN (content delivery network) have an average speed of over 25 Mbps.<sup>6</sup> Progress is being made with faster connections speeds, but there is more to be done to be able to support mass adoption of streaming VR services, not only for today’s devices but future services that will boast even greater display resolutions and frame rates. In the future, guaranteeing suitable data speeds could be a way for network providers to differentiate themselves and create value from the use of VR services.

Source: Ookla

## 5 Proportion of countries globally with average network speeds of over 20 Mbps



## Realism

For AR and VR to achieve widescale adoption, the world as viewed by the user must be as realistic as possible, necessitating significant advancements in visual and audio technology. Again, this is most critical for VR due to the difficulty in rendering realistic 3D environments in real-time. With AR and MR the environment already exists, so the challenge lies in creating realistic and natural-feeling objects to add to the image of the real world.

In order to make VR truly immersive, the digital image needs to be as **natural** as possible, so as to imitate how humans normally see. Firstly, with the screen so close to the user’s eyes, pixel density and quality must be increased to eliminate the screen-door effect (where lines separating pixels become visible), and there must be no lens distortion or chromatic aberrations. Most importantly though, the image must be **spherical** (360 degrees in all directions) and **stereoscopic** (a slightly different image sent to each eye to replicate normal human binocular vision). This is not as simple as

5 Citi Research

6 State of the Internet Q3 2016 report, Akamai



stitching together images taken by multiple cameras around a given point, which can lead to serious problems. Firstly, the stereoscopic image will only feel truly natural to viewers whose interpupillary distance (IPD) matches the distance between the two cameras taking the image, and secondly, not taking into account movements of the user's head and/or eyes can lead to parallax errors, where nearby objects move incorrectly in relation to distant objects. Software corrections and 3D rendering can help reduce these issues, but there is still some way to go for this to be good enough in a live or streaming environment.

With AR/MR an additional complication is for virtual objects to look realistic, with correct illumination, shading and colouring, and accurate interactions with other virtual and real-life objects (anchoring and occlusion). Progress is being made, for example by Qualcomm, on new computer vision and illumination algorithms to dynamically render and overlay realistic AR objects.

**Sounds** heard by the user must also be realistic; hearing is arguably more important than vision in informing a person's sense of space. Creating truly immersive VR experiences requires accurate high-definition 3D (binaural) sound that takes into account the environment (whether a small room or a large hall), accurately depicts various sound sources, and dynamically adjusts as the user moves their head.

Binaural audio is not a new concept and is even present in current VR headsets (such as the Oculus Rift and PlayStation VR). However, with so much effort and focus on the visual side of VR, audio can sometimes be overlooked for simpler, less immersive sound solutions.

In addition to what the user sees and hears, accurate and intuitive interactions with the digitised environment are essential in making the experience as realistic as possible. Firstly, this requires **precision motion tracking** of the user's head, eyes, arms and legs, taking into account six degrees of freedom (6DoF): knowing not only where the user is looking (rotational movement) but also where they are (translational movement). This would allow free movement around the virtual world, and allow for things like looking around corners.

Lastly, **ultra-low latency** is essential. A common complaint in many VR environments today is a noticeable lag of the display following movements of the head and/or arms, leading to glitchy performance and in some cases nausea. End-to-end latency – from the time motion is detected to the photons from the updated image hitting the user's eyes – must be less than 20ms, which is the limit of human perception. The PlayStation VR system claims a market-leading system latency of less than 18ms, but others platforms are yet to reach the critical 20ms threshold.

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## Content

The success of AR/VR in the future will be determined by content. However, this content needs to be specifically designed and **created for the medium**, as opposed to repurposed video content (one of the reasons for the failure of 3D TV) or content that is not actually VR. The problem is that a lot of content described as "VR" recently has simply been based around video captured by 360-degree cameras which, in essence, produce panoramic videos that are then stitched together and fail to offer the same level of realism and freedom of movement as full VR experiences.

The challenge is that creating dedicated AR/VR content is a complex undertaking, and is fragmented across different media types and hardware platforms. Standardisation is therefore important if it is to reach scale and to prevent standard wars (e.g. VHS versus Betamax) of the past. Editing software is also expensive but SDKs are helping to reduce complexity and make AR/VR content creation accessible to more developers.

There are also challenges around collection and **aggregation of content** from different sources (geospatial data, open information, municipal databases etc.) which would require collaboration and agreement on standards from various stakeholders and content providers.

## 4.4 Outlook: separating hype from reality

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AR/VR has been the subject of a huge amount of hype and speculation recently. Industry giants such as Apple, Facebook, Google, Microsoft and Qualcomm are increasingly staking their claim, acquiring start-ups involved in areas such as motion/eye tracking, user interfaces and content development in an effort to be best positioned as the market develops. Facebook especially is expecting big things, having acquired Oculus VR for \$2.3 billion in March 2014, and aiming to create a new communication platform that is “part of daily life for billions of people”.

Hyperbole aside, the real questions lie in what AR/VR aims to achieve. Is the technology going to become a new platform leading to a fundamental shift in the way we work, play and communicate? This assumes that VR headsets eventually replace mobile phones, and early evidence, particularly in the consumer segment, points to a different reality. Although dedicated VR headsets such as the Oculus Rift, HTC Vive and PlayStation VR are receiving the bulk of the attention, they are outsold by the much cheaper mobile-based VR headsets: according to SuperData Research, Samsung Gear VR shipped 2.3 million units in 2016, compared to 745,000 PlayStation VRs and less than half a million HTC Vives and Oculus Rifts. This is not to mention the 84 million Google Cardboard units sold. Of course, price is a major factor, but it does dampen hopes that a dedicated VR headset can be more than just a niche product for tech enthusiasts. So far it appears that mobile-based VR headsets are “good enough” in the majority of use cases.

Creating a new platform would also require a change in user behaviour and considerable interest in the new paradigm. With echoes of the TV industry’s unsuccessful foray into 3D, there have been false starts in AR/VR. Google Glass failed to capture the imagination of the public with concerns around privacy, etiquette and safety, and was eventually discontinued. Elsewhere, North American electronics retailer Best Buy closed just under half of its Oculus Rift demo stations in early 2017 due to lack of interest. It is still hard to predict exactly where AR/VR is heading, and the business models around hardware and content remain largely untested. However, aside from specialised solutions that solve specific use cases in the enterprise segment (which could be many years away from maturity), the future of AR/VR will more likely lie as an extension to the mobile ecosystem, leveraging the billions of smartphones that are already in circulation and becoming a means of accessing content rather than a platform in itself. In this future, the VR headset does not replace the smartphone but rather complements it for specific applications.



**Content – specifically who creates it, who distributes it, and who owns the rights to it – will be key**

The AR/VR market is already estimated to be worth \$1 billion<sup>7</sup> and is expected to grow exponentially over the next few decades – forecasts vary enormously, but some place the market size at more than \$100 billion by 2021.<sup>8</sup> The majority of revenues (over two thirds) is currently controlled by hardware vendors. However, if AR/VR is in fact an extension of the existing mobile ecosystem rather than a platform in itself, then the next few years could see a shift to content becoming the primary revenue driver as hardware becomes

commoditised: Digi-Capital expects content to account for 50% and 75% of revenue for AR and VR respectively by 2020. Content – specifically who creates it, who distributes it, and who owns the rights to it – will be key. As an example, VR streaming of live events enables a whole new range of VR ticketing options. The future opportunity in AR/VR is therefore for content and IP owners ready and able to license for the emerging technology.



7 Deloitte

8 Digi-Capital

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# 5

## Satellites and star wars





## 5.1 Executive summary

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The last six months have seen a wave of announcements and deals in the satellite communications market. Two privately funded companies – SpaceX and OneWeb – are the principal actors but there is a growing tail of others from pure-play operators to aerospace conglomerates.

The major difference compared to most satellite communications efforts is deployment at lower altitude and in much larger volumes to maximise ground area coverage. This has been termed a ‘constellation’ approach. If launch plans play out to completion, SpaceX and OneWeb alone would collectively have roughly 5,500 satellites in orbit, four times the total number of satellites currently in use worldwide for any purpose and eight times the number of communications satellites. Signal strength increases exponentially as altitude decreases. This means a consumer using connectivity ultimately provided by SpaceX could, depending on capacity, use time-sensitive applications such as video calling, streaming and image-heavy websites or apps that would not otherwise be possible via satellite.

The increased density of LEO satellite constellations being proposed is made possible by significant cost reductions at all levels of the supply and production chain. Component costs are reduced by modularising vehicle build through the use of open-standard design specs. Smaller form factors mean more satellites can be launched on a single rocket, reducing launch fees. The assembly chain is also becoming automated, and vertical integration should drive further economies.

The most tangible opportunity for low Earth orbit (LEO) satellites is in rural internet access. GSMA Intelligence forecasts mobile internet penetration to rise from 48% to 60% of the population between 2016

and 2020; some 3.1 billion people will remain without internet access in 2020, with most of these living in rural India, Africa and Southeast Asia.

Satellite as an end-to-end direct-to-consumer option for internet access has generated media speculation and grand visions of ‘reinventing the internet in space’ but there are a number of technical and regulatory obstacles that will make this difficult. The more viable and likely scenario is for satellite operators to sell connectivity on a wholesale basis to the mobile operators, which would acquire and manage the end customer relationship. This would complement existing network expansion efforts among mobile operators and towercos, with satellite providing backhaul and potentially localised radio access networks. If commercial deployment timelines hold, we would expect an accelerating impact on mobile internet take-up from 2020.

The satellite renaissance contrasts with problems faced by Google and Facebook, also part of the crowding arms race in the sky through their investments in balloons and drone technology. Fanfare has outweighed results, with no active commercial deployments and none in sight. For Google, operator partnerships are necessary for success but complicated by the risk of spectrum interference, as evidenced by the recent ITU intervention blocking service in Sri Lanka.



## 5.2 SpaceX and OneWeb – renewing the satellite story

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Satellite is not new. Indeed, a wave of investment and optimism in satellite in the late 1990s and early 2000s ended in bust. However, the last six months have seen a wave of announcements and deals in the satellite communications market. Two privately funded companies – SpaceX and OneWeb – are the principal actors but there is a growing tail of others from pure-play operators (e.g. O3b Networks) to aerospace conglomerates (e.g. Boeing, EADS).

In November 2016, SpaceX filed a request with the FCC in the US for permission to launch 1,600 communication satellites into LEO that would cover mainland US and some territories. This would be the initial phase in a wider plan to deploy a global constellation network of 4,425 satellites over a multi-year period. In December 2016, OneWeb secured a \$1 billion venture investment from SoftBank, adding to an already varied list of strategic corporate investors including Bharti, Qualcomm, EADS and Virgin. OneWeb announced a proposed merger with Intelsat in February 2017, with SoftBank committed to an additional \$1.7 billion investment as part of the deal, but this has now fallen through, with Intelsat unable to reach an agreement with its bondholders (part of Softbank's investment would have helped Intelsat reduce its debt load). The strategic rationale for the proposed merger was based on a combined entity that could offer a differentiated offering of connectivity for consumer broadband, automotive and other IoT applications in addition to traditional

airline and maritime customers. While OneWeb has the potential to significantly upscale satellite production in its own right to service these verticals (it plans to launch 700 satellites in LEO from 2019), further M&A may be considered as a way of accelerating its fleet deployment and avoid the risk of falling behind SpaceX and other competitors.

The announcements have generated significant media coverage. In part, this reflects a connection to fast-growing efforts to commercialise human space flight; Elon Musk, the founder of SpaceX, opines on the potential for putting humans on Mars with SpaceX the means of travel. This is, however, a long-term (if ever) vision for the mass market. The largest realistic impact is of satellite having renewed potential of becoming a scaled channel for internet access and backhaul in countries where internet penetration is low. Globally, 3.9 billion people (52% of the population) do not yet use the internet; the majority of these live in rural Sub-Saharan Africa, India and Southeast Asia.

## 5.3 The constellation model versus traditional satellite

The new constellation approach at low altitude (LEO) augments capacity and reduces costs relative to traditional satellite at step change levels.

On capacity, if launch plans play out to completion, SpaceX and OneWeb would collectively have roughly 5,500 satellites in orbit. This is four times the total number of satellites currently in use worldwide for any purpose (1,400) and eight times the number of communications satellites (700). At full deployment, the constellation networks of SpaceX and OneWeb would, in theory, cover substantially 100% of people who do not yet have internet access versus 80–90% covered by land-based 3G mobile networks. In terms of cost, production is becoming automated with

smaller commoditised components, reducing costs and improving time to market. This is likely to drive down wholesale access costs for operators and, by extension, consumers.

The architecture and performance of communication satellites comes down to three major characteristics: geopositioning, orbit/altitude and satellite density. Below we compare the LEO constellation model pursued by SpaceX and OneWeb (and others) against traditional satellite approaches on each characteristic.

### Geopositioning

Every satellite in orbit is designated based on longitudinal positioning. This is measured in degrees, with coordinates moving either westward or eastward from the Prime Meridian. It is possible for multiple satellites to share the same longitude by occupying different orbit inclinations (higher inclinations move closer to the polar regions). We show two examples in Figure 1 to illustrate how this works in practice:

- Intelsat 34 sits at 55 degrees west over the mid-Atlantic, providing coverage for communications to the Americas and parts of Europe (Inmarsat 5F2 is also on 55 W, servicing maritime and airline customers)
- Chinasat 12 sits at 88 degrees east over central Asia, providing coverage for communications primarily to China.

Source: satbeams.com, UCS

### 1 Coverage area of selected communication satellites in geostationary orbit



In the new LEO constellation model, service is likely to first be concentrated over a limited area for trials and initial commercial launch before broadening out to provide full global coverage over a period of years. For example, SpaceX has indicated that its first batch of 800 will allow it to cover the continental US along with more southerly latitudes over large parts of South America. Only once it reaches the latter stages of the full 4,425 deployment plan will it cover the most northerly latitudes (including Alaska) because it is those satellites that will have higher inclination orbits.

## Orbits and the altitude/signal strength trade-off

This is the most important element of satellite topology. There are multiple types of satellite orbits, which are distinguished by their altitude and inclination (angle from the equator). The key trade-off is that with increasing altitude, ground coverage is increased while signal strength to ground is reduced.

- **Low Earth orbit (LEO, 55% of satellites in use)**

Satellites at LEO are nearest relative to Earth, roughly 800–1200km above sea level (for context, commercial airplanes fly at an altitude of 10km). The rotational period around the Earth takes 225 minutes, which means satellites at LEO circumnavigate the globe approximately six times each day. Lower altitude means it takes less time for signals to make a round trip from satellite to Earth, so LEO satellites also have the shortest latency. LEO satellites are ideal for weather and other observational satellites such as high-resolution imaging for the defence sector.

- **Geostationary Earth orbit (GEO, 35% of satellites in use)**

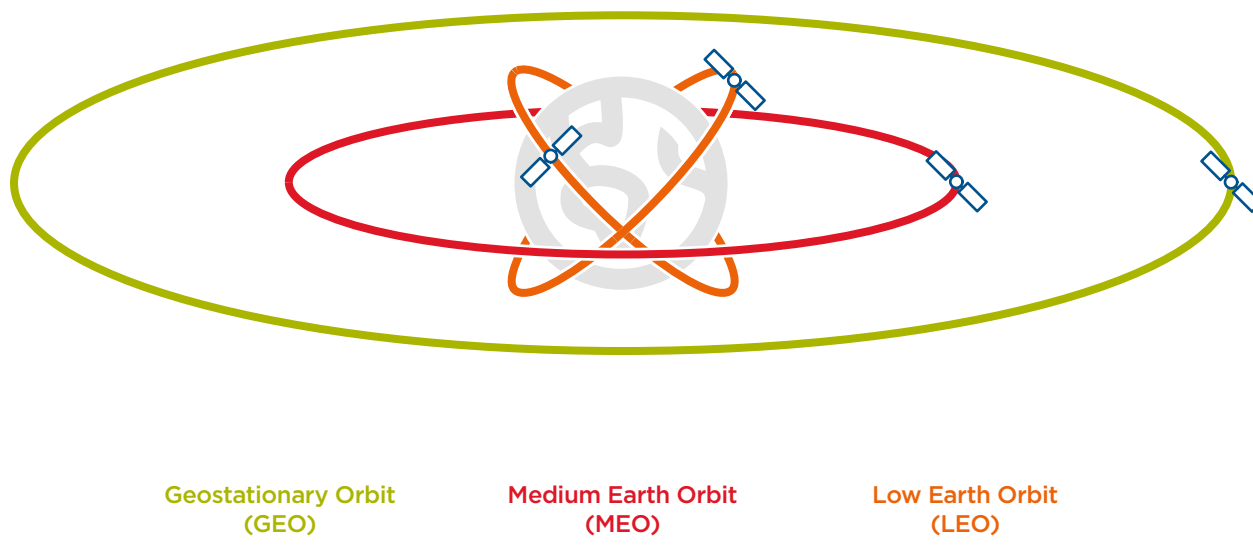
These satellites are furthest away from Earth, occupying an altitude of 35,800km directly above the equator. This altitude is chosen for a specific purpose, which is that the orbital period matches the Earth's rotation (24 hours). This means that for a person on the ground, the position of a GEO satellite remains the same throughout the day, preserving line of sight and reducing the risk that coverage is lost. For this reason, the majority of communication satellites up to now (63%) have been stationed at GEO. Conversely, GEO satellites have a latency 10× longer than LEO (250–280ms)

- **Medium Earth orbit (MEO, 7% of satellites in use)**

Satellites at MEO occupy a broad range of altitudes between LEO and GEO

Source: Harris Caprock

## 2 Orbital paths of satellites based on distance from earth



The new constellation model will deploy at LEO as opposed to GEO. The negative side of the altitude/signal strength trade-off is that the lower altitude reduces ground area coverage. SpaceX has indicated an individual satellite at an altitude of 1,150km will have a ground radius coverage of 1,060km, smaller compared to GEO but mitigated by having a higher density of satellites in the constellation to create overlapping cells. The benefit is that the lower altitude confers a stronger signal and lower latency.

The FCC estimates that existing US satellite operators operating at GEO (Hughes and ViaSat, both of which provide consumer broadband service) have a latency of around 600ms. SpaceX estimates its latency will be 20 times lower at around 30ms, the reduction possible because signal strength increases exponentially as altitude decreases. In practical terms this is important because it means a consumer using connectivity ultimately provided by SpaceX could, depending on capacity, use time-sensitive applications such as video calling, multi-player gaming or video streaming that would not otherwise be possible, or only at very low quality, via satellite.

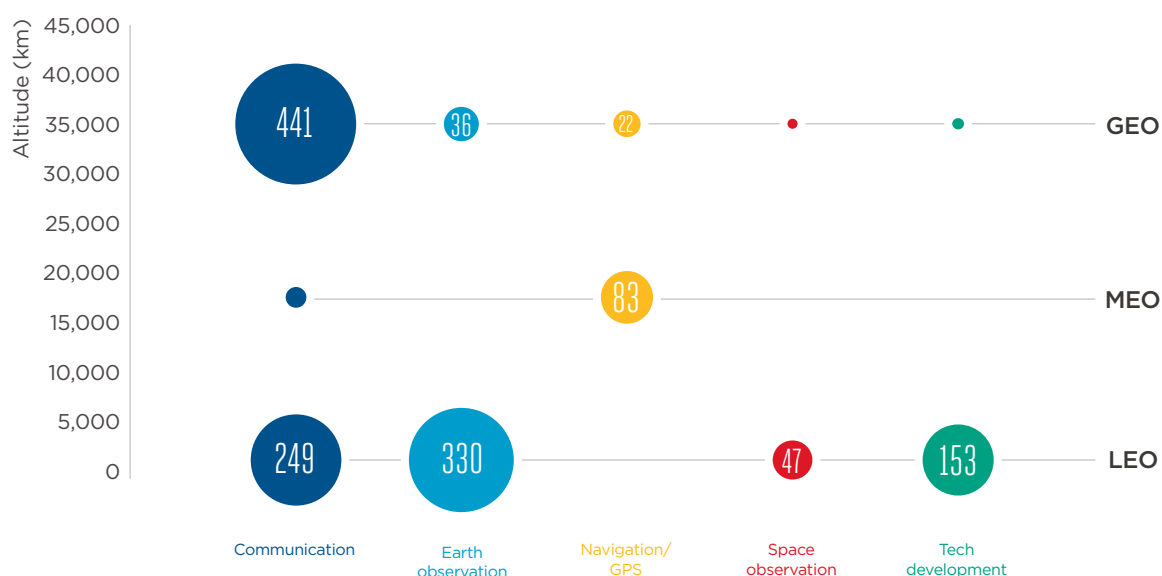
## Density

The other key change with the constellation model is that density is vastly increased to expand coverage area and throughput levels, and allow for more seamless signal transmission between satellites. If launch plans play out to completion, SpaceX will have 4,425 satellites in orbit and OneWeb will have around 700, four times the total currently in orbit worldwide

and dwarfing even the largest satellite owners (see Figure 3)<sup>1</sup>. The Russian Ministry of Defence currently has the highest known number of satellites in orbit with 80, according to the Union of Concerned Scientists (UCS). The US Air Force has 31, the Chinese Defence Ministry has 22. Iridium is the highest volume private operator with 70, Intelsat has 30 and DirecTV has 11.

Source: UCS, GSMA Intelligence

## 3 Global distribution of active satellites (2015)



Categories represent the primary purpose of satellites in active operation. Note the UCS database is based on a manual data gathering process and so will underestimate the true total.

<sup>1</sup> This may well understate the eventual total. Both companies, along with several others including Boeing, O3b and Telesat, have also requested permission from the FCC as of March 2017 for use of V band spectrum (37.5–42.5 and 47.2–52.4 GHz) to launch a further cohort of LEO satellites. SpaceX has indicated that, if approved, it plans to launch a further 7,500 satellites on top of the existing 4,500 constellation. OneWeb plans a further 2,000. Boeing plans up to 2,900. Satellite operators use a variety of spectrum bands for services, including Ka, Ku, C and S bands.

It is, however, an altogether different question as to what speeds will be realised in practice (see Table 1). The overall effect of densification in the sky is the same as that on earth with network cell sites: by loading up a given amount of space with more satellites, the aggregate capacity of the overall network increases. SpaceX has claimed that once fully deployed, its constellation network will be able to support an aggregate downlink capacity of 17–23 Gbps per satellite, with end users reaching ‘up to’ 1 Gbps. This would only allow for 17–23 people to be serviced by the cell assuming each used the 1 Gbps (for comparison, a

typical LTE site using 45 MHz paired spectrum could support roughly 1,750 subscribers each consuming 5 GB/month). In practice, as more people use the network, speeds fall linearly. If 500 people connected to the satellite cell speeds would be reduced to 2 Mbps; if 1,000 connected, speeds would be halved again to 1 Mbps and so on. Playing this out, if SpaceX were to connect 10% of the internet unconnected – roughly 40 million – it would take 40,000 satellites to give each person even 1 Mbps speeds (i.e. 10× the 4,425 announced to now).

Source: SpaceX, FCC, Google, GSMA Intelligence

## 1 Comparison of new class of satellites

|  | GEO satellite* | SpaceX (LEO)  | Google (Loon) | 4G LTE base station*  |
|--|----------------|---------------|---------------|---|
| Altitude (km)                            | 35,786         | 1,150         | 20            | Ground-based  |
| Coverage radius (km)                     |                | 1,060         | 40            | Dependent on spectrum band and site type (e.g. macro, pico) |
| Coverage surface area (km <sup>2</sup> ) |                | 3,529,894     | 5,027         |   |
| Lifespan                                 | 10–15 years    | 5–7 years     | 100 days      |   |
| Downlink speeds (MB/second)              |                | Not yet known | 20–40         | 20–40   |
| Latency (milliseconds)                   | 600–650        | 25–35         |               | 80–100  |

\*Figures are averages for given class of satellite or base station. Specifications for individual installations will fall in a range.

Note: latencies for SpaceX are estimated by the company. Latencies for GEO satellite are based on figures quoted by the FCC for Hughes and ViaSat in the US in 2015



## 5.4 The improved economics of satellite deployment

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The increased density of LEO satellite constellations being proposed is made possible by significant cost reductions at all levels of the supply and production chain. At the bottom of the stack, component costs are reduced by modularising the vehicle build through the use of open-standard design specs, in effect a plug and play model. The result is satellites that are smaller than older generations.

Prospective designs from SpaceX and OneWeb list satellite mass at 385kg and approximately 200kg respectively compared to a median dry mass of commercial and government satellites currently in orbit of around 980kg. Cubesats are even smaller at around 1kg but cannot support the use of on-board electronics and transmission equipment required for large-scale communications, so are not a competitor.

The assembly chain is becoming automated. OneWeb has indicated it plans to build a new 100,000 square foot factory near the Kennedy Space Center in Florida. It has said assembly will eventually be fully automated using advanced robotics (with the help of Airbus), with a target of producing 15 satellites per week at a “fraction of the cost of what any satellite manufacturing facility in the world can produce today”. Close proximity to the space centre limits transportation costs and time between build and launch facilities. The smaller and lighter form factors also reduce rocket launch costs because a higher number can fit on a single rocket. OneWeb has contracted Arianespace and Virgin Galactic to launch its satellites; with Arianespace it plans to launch up to 700 satellites in 21 launches, meaning each rocket will carry between 32 and 36 satellites, two to three times what would have been possible five years ago. The increased efficiency has attracted brokers to sell space on commercial rockets (so-called secondary payloads). If this were to expand to allow price visibility for multiple launch companies, prices would be pushed down further.

Finally, there is also vertical integration. SpaceX has the added advantage of owning its own rockets. The integrated cost structure and tight links with the supply chain allow the company to reduce its launch fees, undercutting its competitors. For example, a launch into LEO on SpaceX’s Falcon9 is listed at \$62 million; per unit mass this equates to roughly \$2,700 per kg, half the cost of launching the same mass with Arianespace. The US military has said that its original contract with SpaceX worth \$83 million for launch of a GPS satellite in 2016 was 40% less than the cost of launching with United Launch Alliance (a joint venture between Lockheed Martin and Boeing). Lower commercial launch fees mean lower margins, but this should not be judged in isolation as a single business unit during one year. The objective is an integrated aerospace operation that includes rocket launch, satellite build and connectivity, with the majority of the cost structure vertically integrated.

Venture-capital investment has recognised the improved economics. Funding into LEO satellites totalled \$284 million between 2010 and 2014.<sup>2</sup> The Google and Fidelity investment of \$1 billion into SpaceX in January 2015 eclipsed the prior five-year total on its own, and this has since been added to by the successive \$1 billion+ rounds into OneWeb. Investment is likely to rise further as cost savings become proven and the range of new revenue models expands (connectivity, imaging, big data are all examples).

Source: SpaceX, Arianespace, GSMA Intelligence

## 2 SpaceX vertical integration lowers cost of launching satellites

|   | SpaceX   |              | Arianespace |
|---|----------|--------------|-------------|
|   | Falcon 9 | Falcon Heavy | Ariane 5    |
| Payload into LEO (kg)                       | 22,800   | 54,400       | 20,000      |
| Price of single rocket launch (\$ million)* | 62       | 90           | 105         |
| Cost per kg (\$)                            | 2,719    | 1,654        | 5,265       |

\*SpaceX prices are listed on its website. For Ariane 5, we estimate an indicative average cost based on total reported order book of €5 billion for 53 launches (i.e. converted to US dollars, \$5.5 billion / 53 = \$105 million per launch)

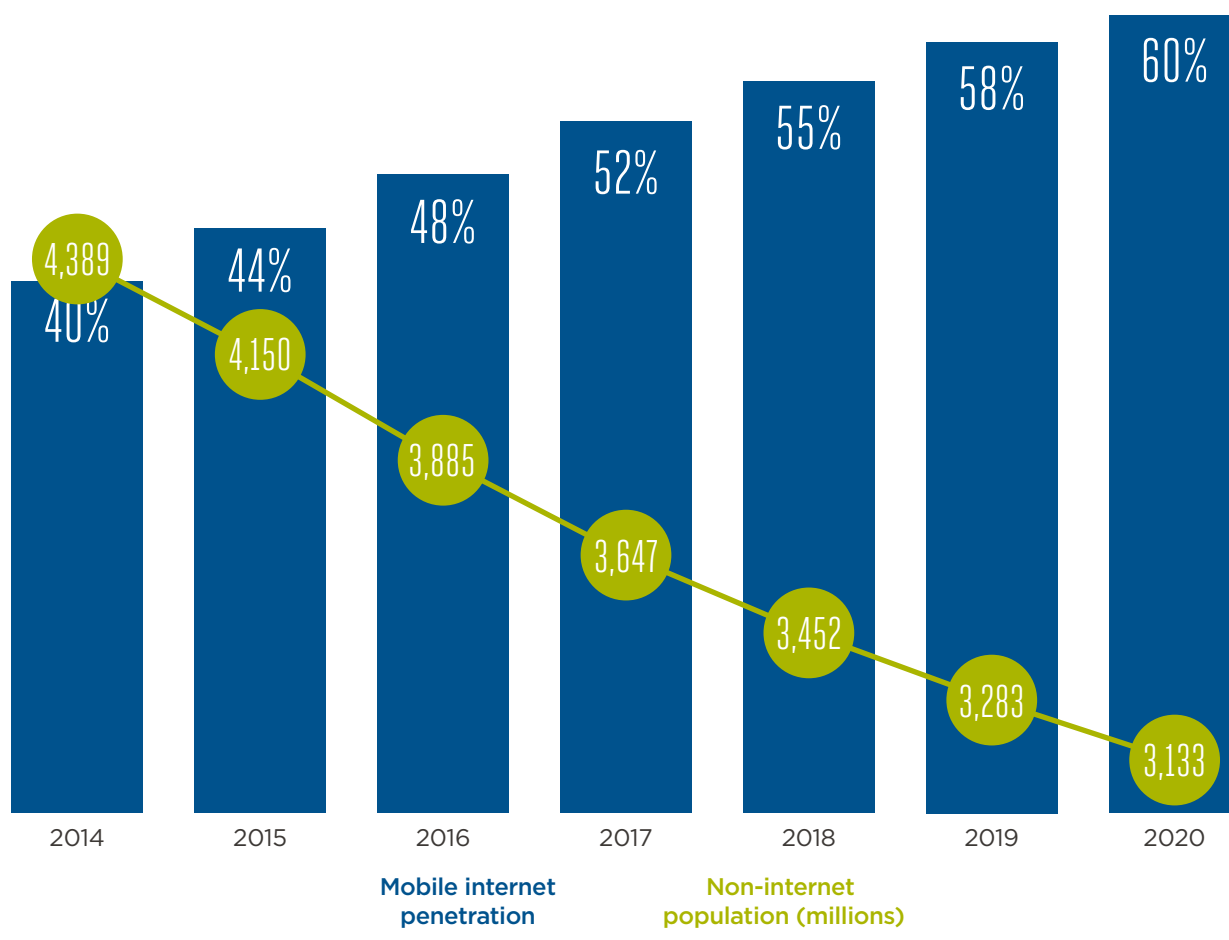
## 5.5 Reinventing the internet in space?

The most tangible opportunity for LEO satellite is in rural internet access. We estimate mobile internet penetration will increase from 48% to 60% of the population worldwide between 2016 and 2020. This equates to an additional 1.1 billion internet users but still leaves 3.1 billion people without internet access in 2020, most of which live in rural areas in India, Africa and Southeast Asia.

The problem is how to reach these 3 billion people with reliable service (e.g. minimum 2 Mbps) at affordable prices (usually expressed as a share of income) while generating an acceptable return. The economics of providing ground-based network coverage to remote regions are challenging for a number of reasons: harsh terrain, long distances for backhaul connections, lack of electricity grid access for base stations (and therefore reliance on diesel generators) and low population density across which to spread capex.

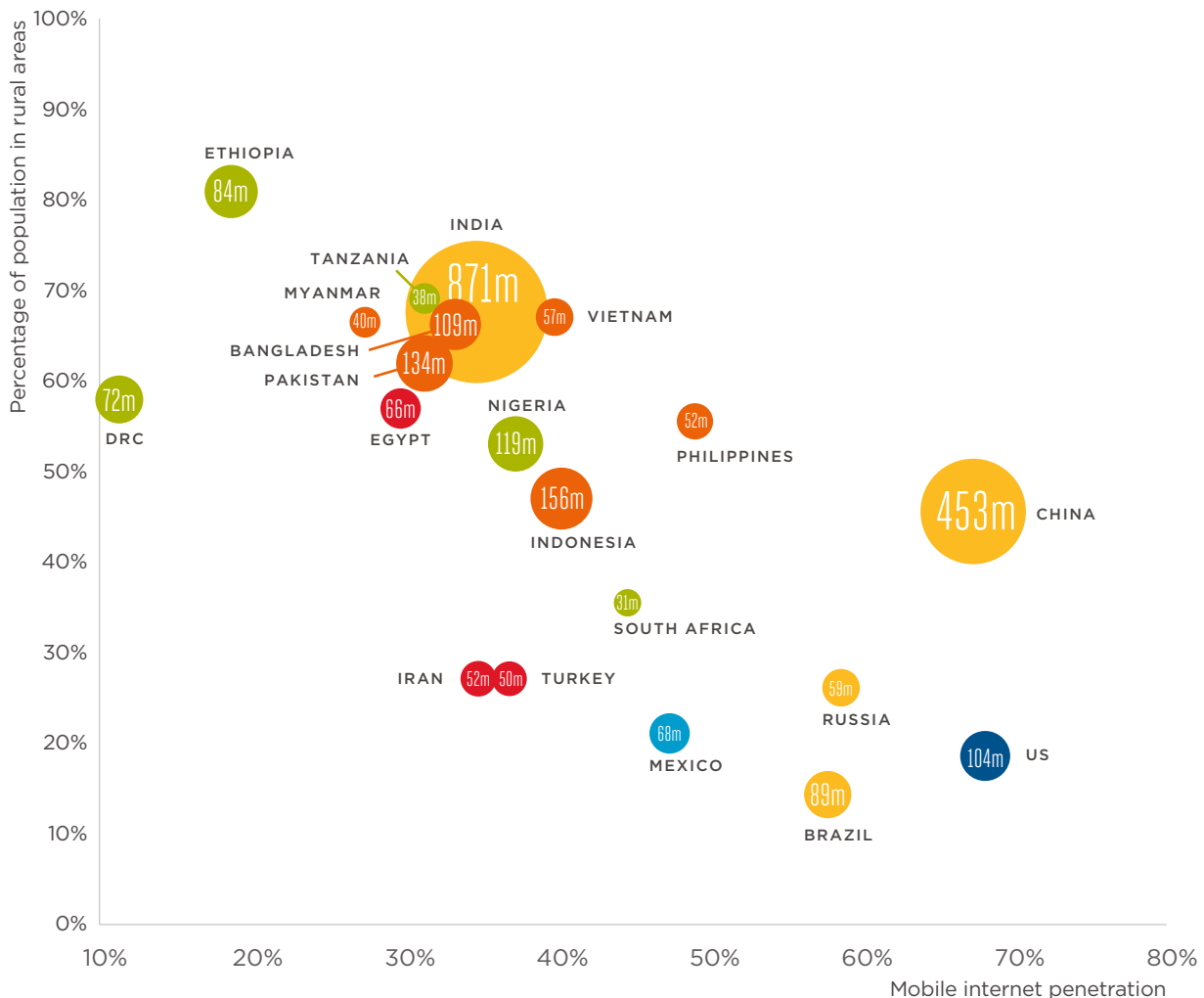
Source: GSMA Intelligence

- 4 On current projections, 3 billion will remain unconnected to the internet in 2020...



Source: GSMA Intelligence

## 5 ...and most people *not* yet on the mobile internet live in rural areas



Bubble size represents the population of non-internet users (e.g. India has 871m people not yet on the internet). Countries shaded by region or economic grouping: Sub-Saharan Africa (light green), Asia (light orange), Middle East and North Africa (red), Latin America (light blue), North America (dark blue) and BRICs (yellow)

We have focussed on SpaceX and OneWeb for a number of reasons – company size, stage of development, strength of investment, presence of strategic corporate partners from adjacent sectors (especially mobile operators), and having charismatic founders (Elon Musk refers to SpaceX's effort as 'reinventing the internet in space'). These are by no means the only companies in pursuit of the 3.9 billion internet unconnected opportunity through an aerial solution. Their nascent rise adds to an already crowding arms race in the sky that includes other

satellite providers (e.g. O3b), Google and Facebook (see Table 3). Technological advancements and improved economics through unit cost reductions and automated manufacturing make satellite a potentially viable complement to terrestrial network expansion. How much of an influence this has on mobile internet subscriber growth will depend on the business model adopted by aerial players and strategic buy-in from the mobile operators. We believe a wholesale connectivity play as opposed to direct-to-consumer is most viable.

Source: company websites and reports

### 3 Goals of aerial altnets

|                                | SpaceX  | OneWeb  | Google (Loon)  | Facebook (drones)  |
|--------------------------------|---|---|--|--|
| <b>Launch date</b>             | <b>Pilot:</b> 2018<br><b>Commercial:</b> planned 2019                             | <b>Pilot:</b> 2019<br><b>Commercial:</b> planned '12-18 months' after (i.e. 2021-22)                            | <b>Pilot:</b> 2013<br><b>Commercial:</b> not started                         | <b>Pilot:</b> 2016<br><b>Commercial:</b> not started   |
| <b>Project mission</b>         | '...in the long term... rebuilding the internet in space'                         | 'Internet access available and affordable for everyone'   | 'Extend internet connectivity to people in rural and remote areas worldwide' | '...connect the world and help more of the 4 billion people who are not online access all the opportunities of the internet' |
| <b>Targets (public domain)</b> | 10% of local internet traffic<br><br>'Majority' of long distance internet traffic | Internet connectivity to 'every unconnected school by 2022'<br><br>'To fully bridge the Digital Divide by 2027' | Not listed   | Not listed   |

Satellite as an end-to-end direct to consumer option for internet access has generated media speculation but has a number of flaws.

The first is simply that the addressable market for companies such as SpaceX, OneWeb and O3b is much lower than the 3.9 billion people who do not yet use the internet. Internet take-up requires network coverage as a baseline but is also affected by affordability, literacy, relevance and localised content. Cross-sectioning the global population on this elucidates an interesting insight. Of the 7 billion people in the world, 3.6 billion use the mobile internet and 3.9 billion do not. Within the 3.9 billion, 66% live within range of a 3G or 4G mobile network but do not use the internet – presumably because it is too expensive or not relevant enough. This means the actual number of people who do not have mobile broadband coverage – the most realistic addressable market for satellite – is only 1.3 billion. This group is spread across multiple countries with multiple regulatory regimes and with multiple mobile operators competing for the same customers.

Secondly, most mobile phones do not have a radio capable of tracking LEO satellite beams.<sup>3</sup> Consumer premises equipment would need to be installed in

end-user homes/buildings for people to actually receive a signal, which would be projected by a Wi-Fi router to PCs and mobile devices over a short range. Given the target demographic of low-income segments, CPE would presumably be subsidised or sold at very low cost, both of which weaken the economics of a B2C model and in any case limit people's connectivity to within close proximity of their home or communal institution (school, hospital etc).

There is then the question of affordability. Internal documents from SpaceX leaked and subsequently revealed in press reports suggest SpaceX is targeting 40 million subscribers by 2025 (roughly 10% of the global non-internet population). The same report lists a target for annual revenue from satellite broadband of \$30 billion by 2025 (from nothing now) and operating profit of \$15-20 billion (from nothing now). Assuming \$30 billion annual revenue refers only to connectivity, this would imply a monthly ARPU of \$62.50. This could be expected for a customer in a rich country such as the US but would be well beyond affordable for the low-income segments in rural Africa and India that the company is seeking to reach. If SpaceX did decide to compete head-on with cable companies and fibre players in the US or European broadband markets,

<sup>3</sup> An exception to this is a partnership between Sky and Space Global (SSG) and SocialEco with a goal of producing a \$20 Android handset that has a radio tuned to a planned SSG network of 200 nano-satellites from 2018.

it is hard to see it being successful given that pricing power sits with those who invest in faster networks, have integrated content offerings, or both. SpaceX would need to spend billions just to roll out a network, and even if it did, costs could quickly spiral if capacity needed to be augmented to offer competitive QoS.

The more viable and likely play is for satellite operators to sell connectivity on a wholesale basis into the mobile operators, who would acquire and manage the end customer relationship. This would complement existing network expansion efforts among mobile operators and towercos, with satellite providing backhaul and potentially localised radio access networks. OneWeb has been most vocal on this approach. SoftBank's investment is a bet on the improved economics of satellite backhaul that would benefit itself directly and indirectly as other operators sign on. Given that backhaul and radio access costs are currently the most prohibitive elements of network expansion to uncovered areas, reductions from the use of satellite would likely cascade down into lower access prices for consumers and have an accelerating impact on take-up.

Google's and Facebook's efforts have generated much fanfare but have amounted to little in the way of concrete deployment. Both want and need partnerships with mobile operators (B2B) but neither has an active commercial deployment. Facebook has had a number of delays with its drone programme; a test flight has occurred in the UK although there are as yet no indications of when (if ever) a commercial installation will be in place with operator partners. Google is more advanced, having trialled its balloons in New Zealand, Australia, Latin America, Indonesia and most recently Sri Lanka. Technological improvements have been made to reduce power consumption and increase longevity of balloons in the air. Regulatory issues continue to bog down the overall effort, Sri Lanka being a case in point. Balloons require access to 700 MHz spectrum to link with operator LTE networks. The government has approved this but the ITU has apparently rejected it on the grounds of interference risk and said it will review its position only in 2019, leaving Google in limbo for a further two years unless ITU policy changes.



### The IoT play for satellite connectivity

The IoT play for satellite connectivity is less talked about but potentially interesting. A market size of 4 million connections is easy to overlook in the context of a cellular M2M market that is 400 million and an overall IoT universe of perhaps 20 billion.

Service is concentrated on verticals that require unit tracking across large distances (military vehicles, commercial trucking, shipping) or that operate in remote areas out of reach of land-based networks (offshore oil rigs, mining pits). A number of established companies operate in this space, including Orbcomm, SkyWave, Iridium and Inmarsat.

Unit ARPU levels charged by existing satellite operators are high (roughly \$5 per month for Orbcomm versus \$1–2 for cellular M2M). We would expect significant reductions if SpaceX or OneWeb were to enter any of these verticals on account of scale economies. SoftBank could execute a vertical integration strategy targeting existing sectors such as logistics and low-power IoT devices (such as utility management) by controlling the

connectivity layer through OneWeb and the IoT chip layer through ARM. Connected cars (though not autonomous driving) have so far been the preserve of land-based cellular connectivity. Satellite could complement this through a handoff once cars drive outside of terrestrial coverage – or even supplant it; SpaceX is the sister company to Tesla, providing the basis for a vertically integrated connected car proposition in addition to wholesale connectivity sold to other car manufacturers. For static IoT devices, the satellite opportunity is more likely to come in rural areas given the plethora of existing connectivity protocols – NB-IoT, Sigfox, Lora – in higher density urban settings. It remains early days, with the companies yet to make firm announcements on deployment plans in IoT and is a space we intend to watch.



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# 6

3D printing:  
from prototype  
to product



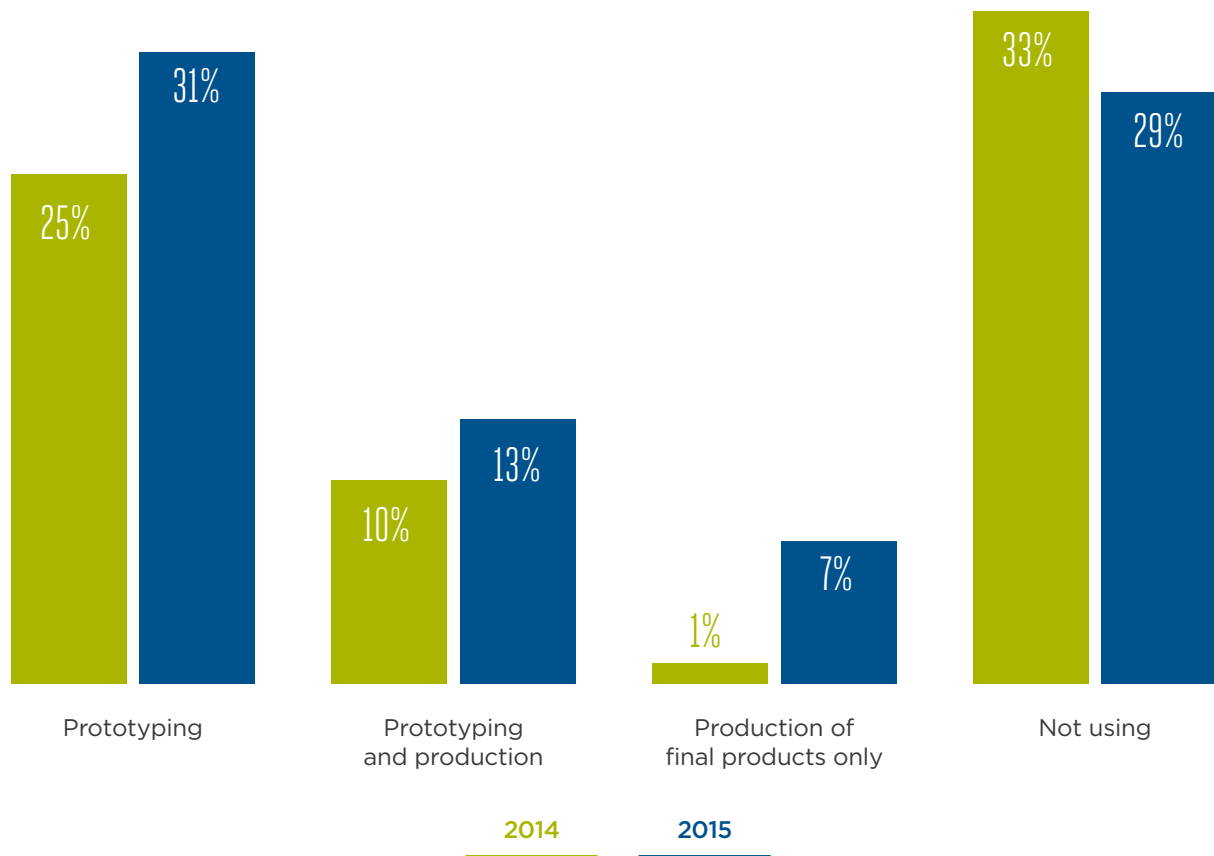
## 6.1 Market update

3D printing (3DP) refers to the layering of natural materials through specialised printers to form objects that can be used in real life. It has been in development since the mid-1980s but activity has accelerated over the last 12-18 months.

- Manufacturing-dependent sectors (e.g. automotive, heavy machinery) are the earliest adopters; as of late 2015 over 50% of manufacturing companies in the US had adopted 3DP for either prototyping or actual market-ready products – a figure that will have increased since then.
- Experimentation and take-up are now expanding (in some cases rapidly) into medical devices, dentistry, defence and aerospace, and architecture.
- This has been driven by lowering costs and use of technologies that allow a wider range of materials to be printed (e.g. fused deposition modelling, sintering).
- 4DP, which adds a time dimension, is nascent but commercial use cases are being explored.

Source: 3D Printing comes of age in US industrial manufacturing, PWC, April 2016

### 1 3DP take-up among US manufacturing companies



## 6.2 Impact will take time but is very real

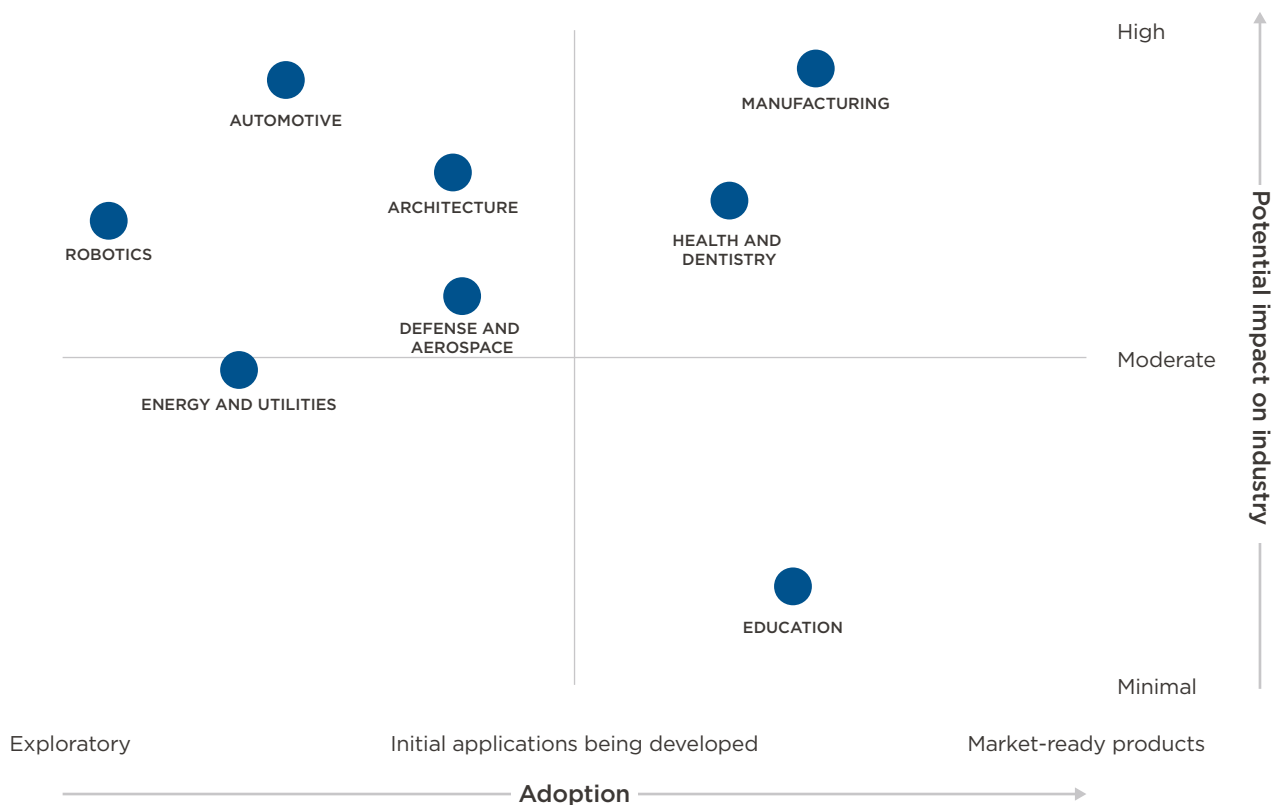
The 3DP impact is likely to be greatest in terms of cost savings in the supply chain (new components, faster delivery).

This has potential to fundamentally change the cost structure of manufacturing and design-intensive industries such as automotive.

Current activity is still mostly focused on building prototypes for product design. As acceptance grows, we expect a shift to market-ready products.

Source: GSMA Intelligence

### 2 3DP: adoption levels versus potential impact







## 6.3 The future: larger builds, dynamic objects

As acceptance of 3DP grows through prototyping and provability, more companies will use the technology to print market-ready components and whole, or near-whole, structures (such as a car chassis or aircraft wing).

A number of R&D centres for innovation have opened. Many of these are cross-sector collaborations, underlining the recognition that joint work and expertise is needed to drive maturity of the technology. Examples include:

- Dubai Electricity and Water Authority (DEWA) centre partnering with GE Additive
- SIA Engineering (an airline maintenance company based in Singapore) partnering with Stratasys.

4D also comes into play for future applications. This would introduce an element of change when an object is exposed to changing environmental conditions (e.g. a water pipe that expands or contracts depending on consumer demand).

Source: company websites and reports

### 1 Examples of current versus future applications from 3DP and 4DP

|                              | Currently in production  | Exploratory stage                         | Future?  | Commercial examples  |
|------------------------------|--|---|--|--|
| <b>Defence and aerospace</b> | Small aircraft parts<br><br>Military accessories (e.g. firearms)             |   | Full segments of aircraft (e.g. wing, tail)  | GE production of 3DP fuel nozzles for aircraft engine (CFM Leap in partnership with Safran, France)                                    |
| <b>Health and dentistry</b>  | Dental crowns<br><br>Replacement prosthetics (e.g. hips)<br><br>Hearing aids | Live tissue cultures for medical research | Organs for transplant  | Embody Orthopaedic production of 3DP hips based on CAT scan data (UK)  |
| <b>Architecture</b>          | Prototypes for buildings, landscapes   |   | Actual structures  | Zaha Hadid Architects, Mediated Matter Group   |
| <b>Automotive</b>            | Car part prototypes<br><br>Rapid replacement parts for Formula 1 cars        |   | Whole chassis<br><br>Printed robots that assemble cars   | Stratasys partnership with McLaren F1 team   |
| <b>Energy and utilities</b>  |  |   | Water pipes that expand or contract in response to consumer demand<br><br>Smart grid integration | GE R&D partnership with DEWA. Goal is lighter and more energy-efficient parts, with applications in solar energy, smart grid and water |

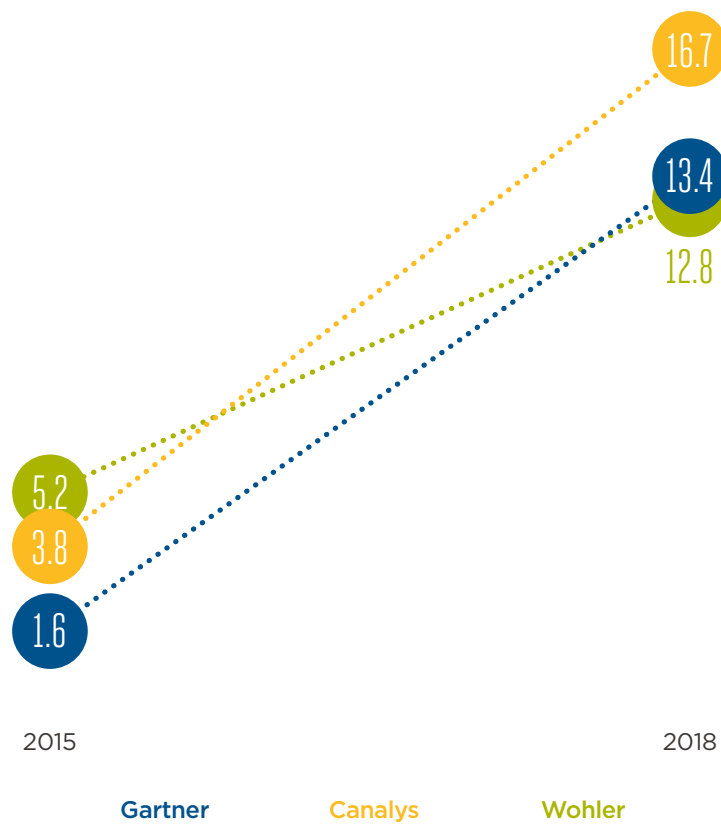
## 6.4 Market size: \$15–20 billion by 2018

A forecast of forecasts suggests a market size of \$15–20 billion by 2018, 3–4× that of 2015. 4D is still nascent, and even by 2020 is unlikely to be more than 5% of the total.

Most of the revenue (90%) comes from printer sales to enterprises. However, the long-term 3D and 4D printing story is much more about cost savings from reduced bill of material costs and less labour-intensive manufacturing. We would expect cost savings to be multiples of the \$20 billion revenue figure.

Source: Forbes, Gartner, Canalys, Wohler

### 3 Projected size of 3D printing market (\$ billion)



Note: market size includes all revenues associated with 3D printing industry including printer sales, accessories, services and materials



## 6.5 3DP ecosystem – going the platform route?

As printer costs fall and the savings to manufacturing processes crystallise, value will increasingly shift to the software layer.

Industry structure is likely to consolidate at both the hardware and software levels, with service players plugging into a limited set of platforms and specialised by vertical (e.g. agencies that manage product design for healthcare or automotive companies). An open question is whether consolidation becomes full stack, with Apple-style control of hardware and software, or whether value mostly sits at the software level (hardware commoditised) and ecosystems are open.

Source: GSMA Intelligence

### 4 Fragmented (current)

|                           |                                     |  |
|---------------------------|-------------------------------------|--|
| Marketplaces              | shapeways <sup>★</sup>              | SupplyBetter   |
| Services and applications | organovo <sup>™</sup><br>sculpteo   | MixeeLabs<br>3DEXTER   |
| Software                  | AUTODESK.<br>TINKERCAD              | Astroprint <sup>®</sup><br>CADspan <sup>™</sup><br>3D printing solutions |
| Printer manufacturers     | DESKTOP METAL<br>ExOne <sup>™</sup> | stratasys<br>hp<br>Airwolf3D   |
| Materials                 | formlabs                            | STRUCTURED POLYMERS  |

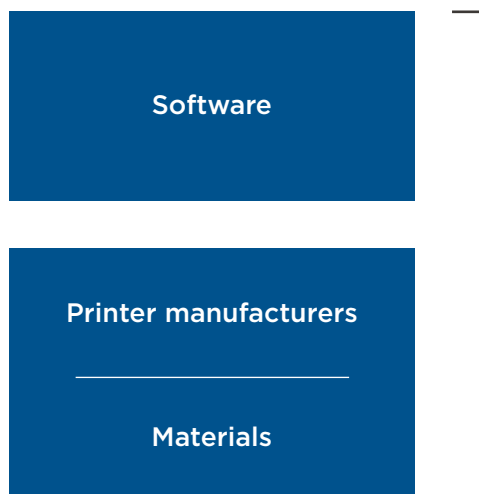
Note: we show primary business line in 3D printing above. Companies may compete in multiple segments (e.g. printer manufacturing and materials).

Source: GSMA Intelligence

## Consolidated platforms (future?)



- ③ Regardless of this, software specialisation will happen and probably be tailored to different sectors that will use 3DP (e.g. healthcare, defence, automotive) as opposed to a one-size-fits-all approach.



- ① Consolidation likely to happen between hardware (print manufacturers) and software layers of the value chain
- ② The open question is the extent to which the software layer is open or closed. An open ecosystem would have many smaller specialist software developers feeding into a smaller group of larger full stack players, whereas a closed model would keep hardware and software development tightly controlled in-house.

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