

# Softwarisation of wireless equipment

## 5G catalyst or long-term threat?

Softwarisation is set to transform the US\$100bn wireless equipment market in the next five years. Rakuten's wireless network in Japan radically redesigns the network's structure – shifting processing functions from specialised base station equipment towards more standardised server hardware away from the cell site, while leveraging software to efficiently allocate capacity and deliver extreme automation. Dish in the US says it could follow this path to an even greater extent, and we expect multiple telcos to follow given significant capex and opex savings. This could accelerate 5G adoption, but also poses transformational challenges to vendors. We lay out a roadmap, key bottlenecks and vendors' capabilities, while setting out key factors to monitor as they transition from hardware sales to software provision. Stocks in focus include **Nokia, Ericsson, Rakuten, Cisco, Samsung, NEC, ZTE and Fujitsu.**

**Alexander Duval**  
+44 20 7552-2995  
alexander.duval@gs.com  
Goldman Sachs International

**Rod Hall, CFA**  
+1 415 249-7437  
rod.hall@gs.com  
Goldman Sachs & Co. LLC

**Ikuo Matsushashi, CMA**  
+81 3 6437-9860  
ikuo.matsushashi@gs.com  
Goldman Sachs Japan Co., Ltd.

**Masaru Sugiyama**  
+81 3 6437-4691  
masaru.sugiyama@gs.com  
Goldman Sachs Japan Co., Ltd

**Allen Chang**  
+852 2978-2930  
allen.k.chang@gs.com  
Goldman Sachs (Asia) L.L.C.



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# List of additional contributing authors

**Daiki Takayama**

+81 3 6437-9870  
daiki.takayama@gs.com  
Goldman Sachs Japan Co., Ltd.

**Andrew Lee**

+44(20)7774-1383  
andrew.j.lee@gs.com  
Goldman Sachs International

**Brett Feldman**

+1(212)902-8156  
brett.feldman@gs.com  
Goldman Sachs & Co. LLC

**Michael Bishop**

+44(20)7552-4248 |  
michael.bishop@gs.com  
Goldman Sachs International

**Tina Hou**

+86 21 2401-8694  
tina.hou@ghsl.cn  
Beijing Gao Hua Securities  
Company Limited

**Giuni Lee**

82(2)3788-1177  
giuni.lee@gs.com  
Goldman Sachs (Asia) L.L.C.,  
Seoul Branch

**Bruce Lu**

+852-2978-6368  
bruce.lu@gs.com  
Goldman Sachs (Asia) L.L.C.

**Hameed Awan**

+44 20 7774-8131  
hameed.awan@gs.com  
Goldman Sachs International

**Aakriti Kakkar**

+1(212)934-6318  
aakriti.kakkar@gs.com  
Goldman Sachs India SPL

**Toshiya Hari**

+1 646 446-1759  
toshiya.hari@gs.com  
Goldman Sachs & Co. LLC

**Mark Delaney, CFA**

+1 212 357-0535  
mark.delaney@gs.com  
Goldman Sachs & Co. LLC

**Ashwin Kesireddy**

+1(415)249-7489 |  
ashwin.kesireddy@gs.com  
Goldman Sachs & Co. LLC

**Lynn Luo**

+886(2)2730-4244  
lynn.luo@gs.com  
Goldman Sachs (Asia) L.L.C.,  
Taipei Branch

**Jin Guo**

+86(21)2401-8943  
jin.guo@ghsl.cn  
Beijing Gao Hua Securities  
Company Limited

**Jeff Kim**

+82(2)3788-1790  
hyungsik.kim@gs.com  
Goldman Sachs (Asia) L.L.C.,  
Seoul Branch



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# Softwarisation

in numbers



**\$100bn**

Size of wireless market.

## COST SAVINGS



**50%**

Capex savings.



**35%**

Opex savings.

## EFFICIENCY GAINS



**100s**

Technicians to run the network  
vs. 1000s prior.



**12 months**

Time taken to build Rakuten  
nationwide wireless network from  
scratch



**10 minutes**

Time taken to deploy radio site in a  
virtualised network vs. 3 weeks to deploy  
radio in a traditional network.



**30 km**

Distance between Distributed Unit and  
cell site in a fully virtualised network vs  
processing being done on base  
stations in a traditional network.

## SCOPE AND POTENTIAL



**>\$5bn**

Investment by Rakuten's  
4G Network.



**6-12**

Number of telcos GS expects to  
softwarise in the next 3-5 years.



**7+**

Vendors who can provide RAN  
functionality in the new world vs. 4  
traditional RAN vendors.



**11%/4%**

Incremental upside case to PT for  
Nokia/ ERIC vs. incremental downside  
case 18%/19%.

Source: GS, Company data, Senza Fili, Rakuten, Telegeography

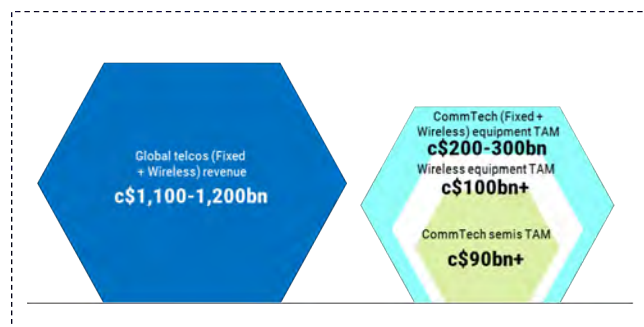


## Portfolio Manager Summary

We believe softwarisation of wireless equipment will have a significant impact on this US\$100 bn market in the next five years, potentially accelerating 5G, but also posing transformational challenges to vendors.

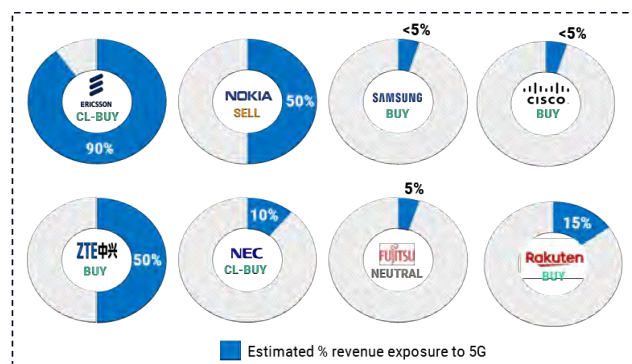
- **Softwarisation involves a shift from processing network functions on specialised equipment towards more standardised hardware away from the cell site (with real-time/non-real time functions performed on an edge cloud server/datacentre), i.e., virtualisation. However, it *additionally* involves use of software to allocate capacity dynamically between different areas of the network and automate its running, while decoupling provision of hardware and software (from a vendor perspective).** The announced launch of Japanese telco Rakuten's wireless network radically redesigns the network structure in this direction. 6-12 further telcos are working on wireless virtualisation in coming years.
- **Our industry discussions suggest telcos could see up to c.50% capex savings (efficient capacity utilisation) and c.35% opex savings (due to automation), albeit *longer term*.** Better economics for telcos could help drive the mid-term ramp-up of 5G. That said, the shift from selling and servicing specialised hardware to providing software could pose significant challenges to wireless vendors.

**Exhibit 1: CommTech equipment TAM is estimated to be US\$250bn, with the wireless market having US\$100bn+ share within this**



Source: Company data, Goldman Sachs Global Investment Research

**Exhibit 2: Selection of key impacted tech companies % exposure to 5G (i.e. exposure to wireless networks)**



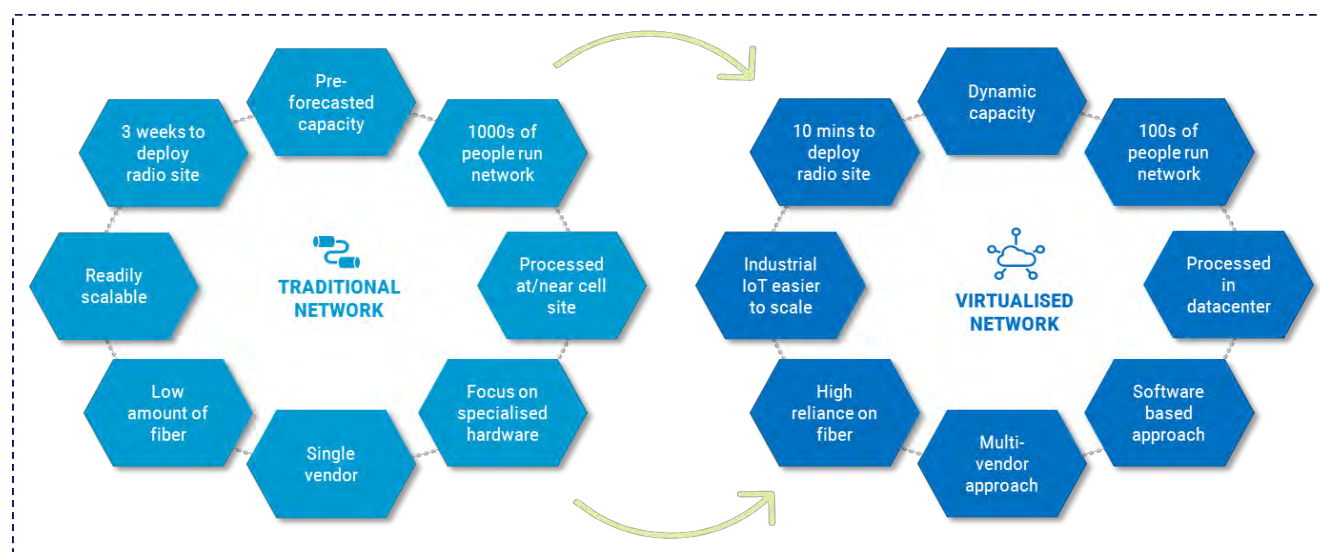
Source: Goldman Sachs Global Investment Research

- **We present a roadmap for investors and detail factors to weigh up vendors' scope to monetise software and offset hardware commoditisation.** While we reiterate our Sell on Nokia and remain Buy on Ericsson (on Conviction List), our scenario analysis implies 11%/18% and 4%/19% incremental upside/downside. We analyse implications for Buy-rated NEC (on Conviction List), Cisco, ZTE and Rakuten (*see upgrade note [here](#)*).
- **While we see longer-term impacts from softwarisation, we note 1) near-term cost advantages (e.g., at Rakuten) should not be overstated** as Japan is already virtualizing part of the network; 2) **bottlenecks** could slow rollouts and **reduce cost advantages (e.g., site procurement)** - Rakuten's initial launch will reportedly be smaller than initially thought; and 3) Rakuten's wireless network is **unproven**.

### Softwarisation shifts processing to datacentre and automates network

- While there has been a trend towards virtualisation in the context of the fixed-line part of the network, there has been a greater degree of scepticism as to its applicability to the wireless realm. While in wireless networks today processing takes place on specialised hardware on the cell site/tower, we see the beginning of a trend towards **shifting base band processing into an edge cloud server/datacenter away from the cell site to be run on a more standardised server hardware**. We note the upcoming announced launch of Rakuten's wireless network in Japan (in October), which radically redesigns the network structure in this direction, and increasing efforts by established telcos to pursue similar approaches. Our industry discussions suggest 6-12 telcos are working on various approaches to virtualisation.
- Thus, while it was previously thought virtualisation of network equipment would predominantly be limited to the fixed-line domain, we argue that **recent developments suggest meaningful scope for cloudification of both real-time critical and non real-time functions in wireless networks in the long run**.

**Exhibit 3: Softwarisation of wireless entails less human intervention, making it faster to activate cell site and cheaper to run**  
Characteristics of the new virtualised network vs. the traditional network



Source: Company data, Goldman Sachs Global Investment Research

- **New software approaches associated with virtualisation offer scope to reduce capex meaningfully.** In particular, that being pursued by Rakuten envisages most areas of the network being run at or near full capacity, with the ability dynamically to divert large amounts of network resources from other areas to those where spikes in traffic occur. This contrasts with the traditional approach, where such flexible capacity allocation is not possible and most domains of the network are run at a much lower capacity utilisation level.
- Moreover, a key tenet of the new approach is that human intervention in the running of the network will be reduced to an absolute minimum, substituted for by automation. **We argue this can have scope to reduce the opex involved in**

running telco networks, which we believe is significant given that data growth continues at 30%+ per annum.

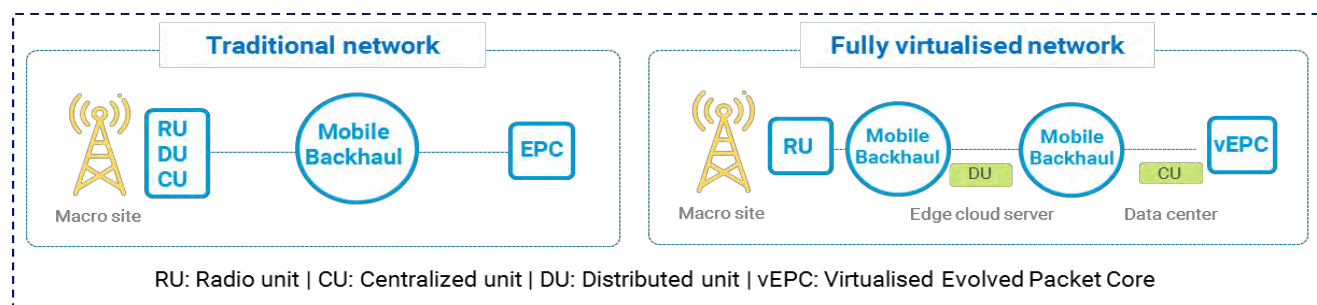
- Industry participants have suggested 50%/35% capex/opex savings vs. a traditional network.

#### New network structure allows faster deployment; frees up tower space

- In basic terms, the shift to a virtualised approach involves the antenna and radio unit of the base station remaining on the tower, but with its key processing elements moving to the edge cloud server/datacentre away from the cell site. The non-real time functions (i.e., Centralised Unit processes) can be virtualised in a datacenter, while the real-time functions (i.e., Distributed Unit) are shifted to an edge cloud server (between the datacentre and the cell site). Thus, the base band unit no longer remains on the cell site/tower.

**Exhibit 4: In a fully virtualised network, base band processing (Centralized Unit and Distributed Unit network elements) moves to the datacenter/edge cloud server with just the radio unit and antennas left at the macro site**

Schematic diagram of the network structure (classical vs. fully virtualised network)



The DU has to remain within 30km from the radio site due to CRPI/timing requirements and the speed of light

Source: Company data, Goldman Sachs Global Investment Research

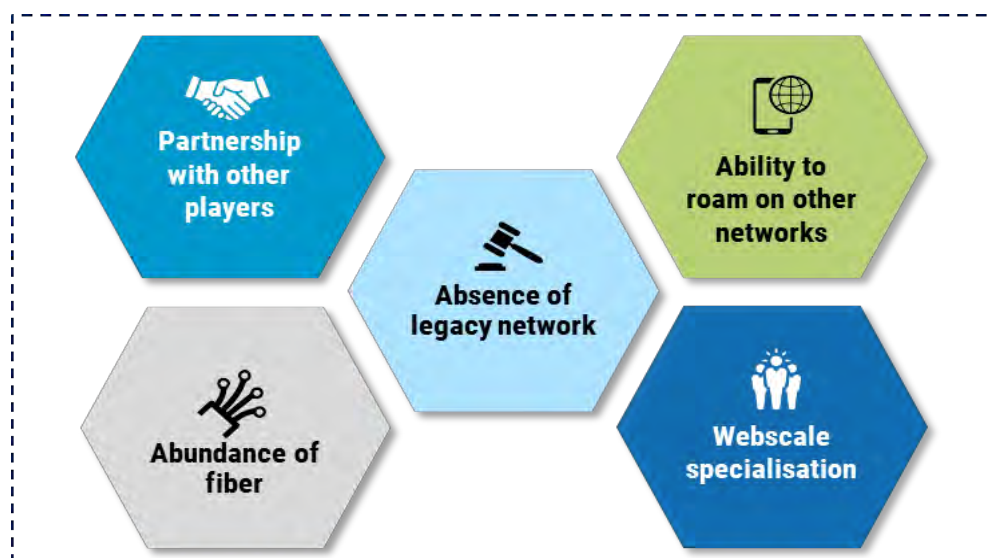
- As such, this puts increased emphasis on having a strong fixed-line backhaul network to connect up antennae with the domains in the network where processing now occurs (i.e., in the datacentre). We note the Distributed Unit (DU) can be on an edge cloud server up to 30km away from the cell site (vs. processing of real-time functions being done on the base station in a traditional network), and the Centralised Unit (CU) can be virtualised in a datacentre up to 200km away from the cell site. Thus, it offers significantly higher scope for centralising the processing of data from a large number of base stations, rather than each base station doing its own processing. This drives energy and other cost savings.
- While it was previously thought that only functions that were *not* required to be executed in real time could be virtualised (e.g., subscriber management and provisioning), Rakuten's implementation involves real time specialised functions being executed away from the base station. Thus, while it was previously thought that non-critical functions would be executed by a Centralised Unit (CU) that would sit in the datacentre, with a Distributed Unit (DU) at the cell site, Rakuten's implementation effectively involves shifting both the CU and DU away from the cell site.

- **Given that the cell towers will now essentially only need to accommodate the antenna and radio, we believe this will *potentially* allow more antennas to be accommodated. We believe this will be important in a 5G world (as innovations such as Massive MIMO require a significant increase in the number of antennas).** This could potentially accelerate the extent to which more advanced 5G functions are possible mid-term, as techniques such as beamforming are utilised. That said, we note in the long term Massive MIMO could involve more processing on the cell site (radio unit) which may entail more processing costs (partly offsetting softwarisation benefits).

#### **Rakuten plans to launch 4G network in October 2019; 5G to follow in 2020**

- **Internet services company Rakuten (which has strong positions in e-commerce and financial technology in Japan) plans, through its subsidiary Rakuten Mobile Network (RMN), to launch a nationwide network in Japan in October 2019, with an innovative architecture that allows for full virtualisation according to the principles described above.**

**Exhibit 5: We see multiple factors which support Rakuten's ability to launch fully virtualised 4G/5G networks**



Source: Company data, Goldman Sachs Global Investment Research

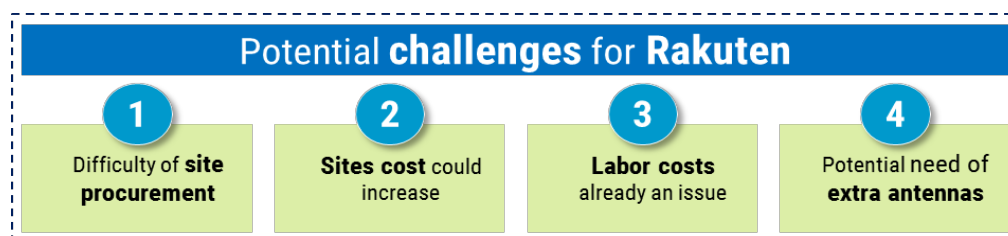
- **We note that this will be the world's first cloudified network, with full virtualisation from radio access network (RAN) to core with end-to-end automation for both network and services.** Radio access will initially be 4G LTE (macro and small cells) and Wi-Fi, with plans for **5G radio technology to be added in June 2020.**
- **Key technology bricks include: virtualised RAN** (from Altiostar), **virtualised Evolved Packet Core** (from Cisco), **IMS** (from Nokia and Mavenir), **BSS** (from Netcracker). It will also incorporate virtualised network functions related to security etc. We provide an illustration of potential key vendors for both 4G and 5G on the Rakuten network in Exhibit 19.



- **Our industry discussions suggest that several factors are of significance in facilitating Rakuten's ability to softwarise a network** including the relatively large amount of high-quality fiber infrastructure in Japan (allowing for strong responsiveness of the backhaul and hence the network), its partnership with Altiostar (which could give it advantages in terms of understanding vRAN) and its webscale expertise (i.e., advanced capabilities in scaling traffic up and down and managing "bursts" of data in a datacentre context).
- **That said, we are cautious on the cost advantages of Rakuten's network near term vs. other telcos and highlight certain key risk factors.** We note **1) near-term cost advantages from implementations such as Rakuten's should not be overstated** given Japan is already virtualizing part of the wireless network. **2)** We detail bottlenecks that could slow down rollouts such as Rakuten's and **reduce cost advantages meaningfully (e.g., site procurement).** We note on August 16 the Nikkei reported that the scale of Rakuten's launch may initially be smaller in October 2019 than originally envisaged, given issues related to labour shortages and wiring capacity (albeit we do not see these as technical show stoppers). **3)** Rakuten's fully virtualized wireless networks are **yet to launch and hence are unproven.**

**Exhibit 6: We see various potential bottlenecks for Rakuten's rollout and reasons for cost savings being potentially smaller than initially expected**

Examples of potential challenges for Rakuten



Source: Company data, Goldman Sachs Global Investment Research

### Multiple long-term cost benefits to telcos from softwarisation

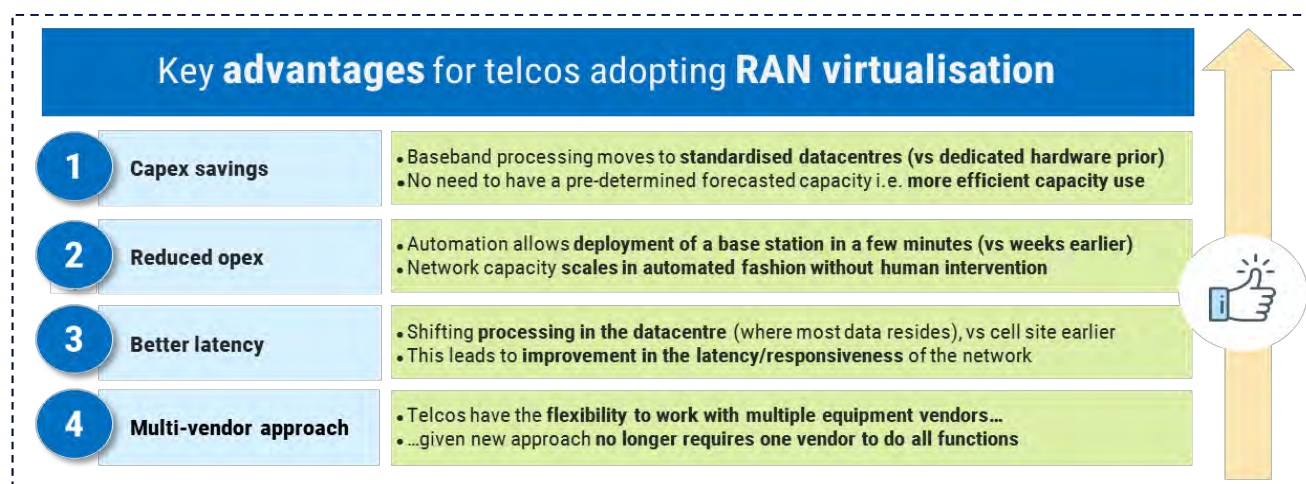
- **We see multiple *longer-term* benefits of the new approach, with scope to reduce capex meaningfully: virtualisation envisages most areas of the network being run at or near full capacity, with the ability dynamically to divert large amounts of network resources from other areas to those where spikes in traffic occur.** This contrasts with the traditional approach, where such flexible capacity allocation is not possible and most domains of the network are run at a much lower capacity utilisation level, in order to accommodate incremental traffic when it occurs. By definition, the new approach thus allows for a lower capex outlay for a given amount of overall network capacity.
- **Another reason telcos could see reduced capital investment needs is due to the dynamic whereby expensive specialised hardware is replaced by processing taking place on edge cloud server hardware (for DU) and standardised datacentre hardware (for CU).** This would in our view likely make it harder for vendors of traditional hardware to justify as high a price (for each base

station). That being said, we believe that software which drives network functionality/orchestration will have more value, meaning there will be value for vendors to capture from this (likely with higher margins).

- According to Nokia, virtualisation could lead to **capex savings up to high single-digit to teens** for network operators. Additionally, it estimates **opex benefits for operators can be 20%-30%**, resulting in **30%-35% overall cost savings** (assuming end-to-end fixed and wireless implementation) - albeit this would be more achievable in the longer term assuming industry manages to softwarise effectively.
- **Moreover, a key tenet of the new approach is that human intervention in the running of the network will be reduced to an absolute minimum, substituted by automation. We argue this can have scope to reduce the opex involved in running telco networks, which we believe is significant given that data growth continues at 30%+ per annum.** Notably, whereas a nationwide wireless network may require e.g. several thousand people to run it, a fully virtualised one could require only hundreds.

#### Exhibit 7: Virtualisation of the wireless network will lead to incremental cost savings for the telcos

Key advantages of RAN virtualisation



Source: Company data, Goldman Sachs Global Investment Research

- **However, we note that given extra fiber fronthaul/backhaul requirements in some regions, depending upon fiber availability, this could to some degree offset capex savings.** That being said, we still believe more standardised hardware for both the edge cloud server (for DU) and standardised datacentre hardware (for CU) can lead to net capex benefits overall for telcos. Furthermore, **operational cost savings are in our view clear**, e.g., energy savings (and *potentially* some space savings on the cell site) from a more centralized processing approach.
- **Other benefits include scope for more rapid cell site deployment (10 mins vs. 3 weeks “theoretically”), scope to reduce human error in network management and, importantly, potential for greater telcos bargaining power/tech innovation**

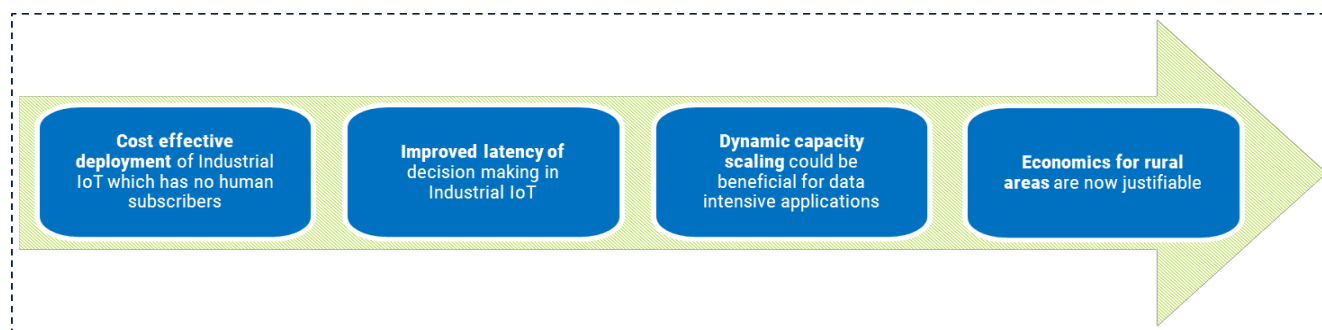
given the new approach of players like Rakuten/Cisco/Altiostar decouples provision of hardware from provision of software.

- **That said, we note the *near-term* cost advantages from implementations such as Rakuten's should not be overstated** given 1) some other Japanese telcos are already virtualizing part of the wireless network (i.e., CU), e.g., NTT Docomo. 2) While the cost of Rakuten using IA servers and Altiostar software may be cheaper than traditional telcos' implementation of CU, the efficiency of the CPU utilization may not be hugely different on the CU on Rakuten's implementation vs the approach on traditional networks. However, we believe over time Rakuten's approach to virtualise DU could yield benefits.

### Softwarisation could help catalyse deployment of 5G use cases long term

- **In our view, softwarisation of the wireless network, and associated cost savings, could potentially help accelerate the application of 5G technology** to use cases such as Industrial IOT.
- **First, given that industrial IOT use cases (e.g., factory automation) do not have a pre-existing large number of consumers to provide an economic underpinning for data provision**, cost effective deployment via virtualised solutions (which help reduce capex/opex needs) may help drive uptake.

**Exhibit 8: Virtualisation can help accelerate the deployment of 5G use cases longer term**



Source: Company data, Goldman Sachs Global Investment Research

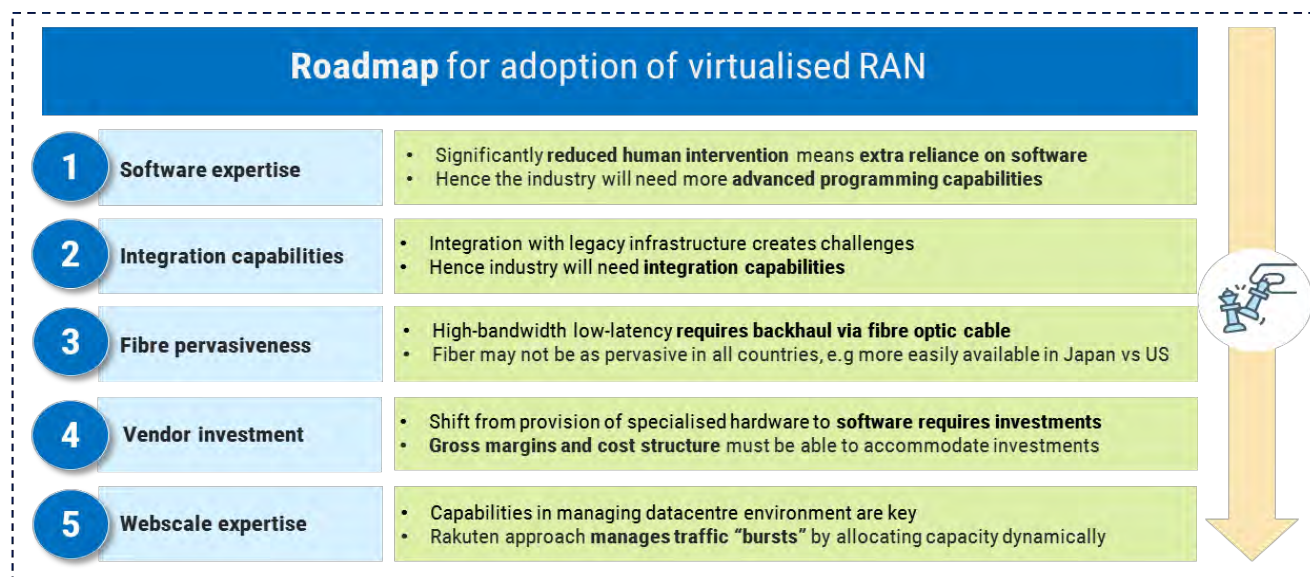
- **We expect the Industrial IOT rollout of 5G to happen *after* the initial consumer rollout, and likely be associated with the standalone 5G standard (for Industrial IOT) which has yet to be finalised.** This means that large-scale rollout is more likely to happen in 2022 onwards, as per our report *Global Technology: 5G: Moving from the lab to the launchpad*, given the need to finalise specific standards and business models. At that point in time, it is possible virtualisation could help accelerate the pace of use case adoption.
- **Second, we believe that the viability of Industrial IOT could be improved by harnessing virtualisation.** In particular, this use case, e.g., in a factory/automated driving setting, typically leverages 5G fast connectivity, allied to the collection of extremely large quantities of data from sensors, and real-time analysis of this data. Given the proximity of the data to the place where the processing will occur, we believe this will improve latency/speed of decision-making.

- **Third, for use cases such as Automated driving**, where the volume of data collected and sent over the network could potentially be extremely large at certain times of day, **the capability to scale capacity up or down dynamically could be particularly advantageous.**

### Roadmap for broader adoption; challenges/bottlenecks

- **We see challenges for broader longer-term adoption of a highly virtualised software-centric approach.** We lay out a roadmap for wider telco usage.

Exhibit 9: We lay out a roadmap for broader adoption and see various bottlenecks/challenges



Source: Company data, Goldman Sachs Global Investment Research

- **First, we believe the ecosystem will need to improve software capabilities, e.g., programming language knowledge.** Given that the fully virtualised approach effectively aims to eliminate human intervention in running the network, it is reliant on automation via software. While we see clear advantages to this, it could also mean that if there is a software issue that takes time to fix, this could create significant problems. This could create reputational issues that could retard the proliferation of virtualised wireless networks.
- **Second, vendors will need to have the capabilities to integrate the installed footprint of legacy hardware with new/virtualized hardware.** While Rakuten is a greenfield build (from the ground up), other telcos would need to support legacy installed footprint of hardware.
- **Third, moving processing to the edge cloud server/datacentre is predicated upon having extensive fiber networks in a particular network**, so as to have a rapid and reliable backhaul (between the cell tower and the datacentre). This may not apply in every region.
- **Fourth, vendors will need to demonstrate sufficient investment capacity.** Shift from provision of specialized hardware to software requires investments in the context of wireless equipment vendors that are still restructuring. Gross margins



and cost structure must be able to accommodate investment needed for this technology shift.

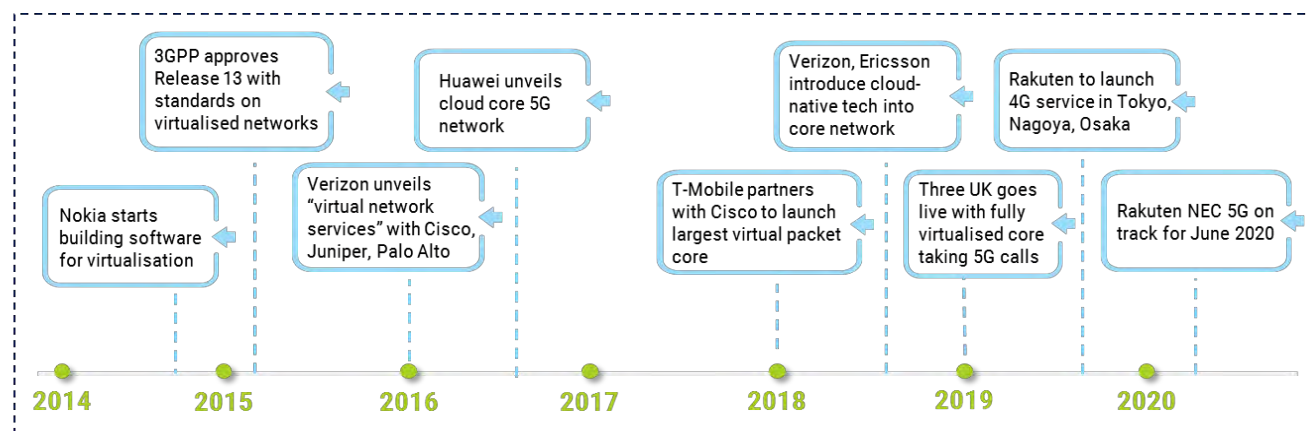
- **Finally, as things stand, there is some debate as to the ease with which every 5G application may be virtualised.** For example, some argue that industrial IOT is more apt for virtualisation, given features may be less complex, whereas this may be less so for some consumer use cases.
- **We also believe traditional equipment vendors need to understand webscale techniques.** Rakuten's approach involves managing "bursts" of traffic and allocating capacity in the datacenter.
- **We note the industry will need to coalesce around a strategy for hardware standardisation** if they want to realise the full cost benefits (so that the industry could open up to multiple vendors).
- **As such, in the near term, decoupling of software and hardware provisions may actually have a bigger impact in terms of cost** than utilization of the datacentre (for non-real time functions) and edge cloud (for real-time functions) for telcos.
- **While Rakuten is due to launch its 4G network in Japan in October 2019, and plans to launch its 5G network in 2020, we believe there could be various near-term bottlenecks to the company's implementation as detailed below.**
- We note 1) the near-term **cost advantages from implementations such as Rakuten's should not be overstated** given Japan is already virtualizing part of the wireless network (Japanese carriers have been adopting the RRH/C-BBU architecture from 4G, having computer parts located in fewer locations). 2) We detail bottlenecks that could slow down rollouts such as Rakuten's and **reduce cost advantages meaningfully (e.g., site procurement)**. We note on August 16 the Nikkei reported that the scale of Rakuten's launch may initially be smaller in October 2019 than originally envisaged given issues related to labour shortages and wiring capacity (albeit we do not see these as technical show stoppers). 3) Rakuten's fully virtualized wireless networks are **yet to launch and hence are unproven**.

#### 6-12 telcos to virtualise RAN, aided by a growing vendor ecosystem

- **Our industry discussions suggest 6-12 telcos (aside from Rakuten) are working on** virtualisation of wireless to varying degrees (specifically V-RAN, associated network functions and automation), and we expect them to make significant progress in this space in the next 3-5 years (with players working on Greenfield networks expected to be faster vs existing networks). **We see a diverse regional approach in shifting to virtualisation of wireless specifically.** That said, we note the direction of travel towards *broader* virtualisation is clear, with all vendor RFP discussions with telcos globally typically involving some element of virtualisation (at least of the core, and often regarding virtualisation of OSS/BSS).

**Exhibit 10: We believe there has been significant interest amongst telcos in shifting towards RAN virtualisation**

Timeline of key events



Source: Company data, Goldman Sachs Global Investment Research

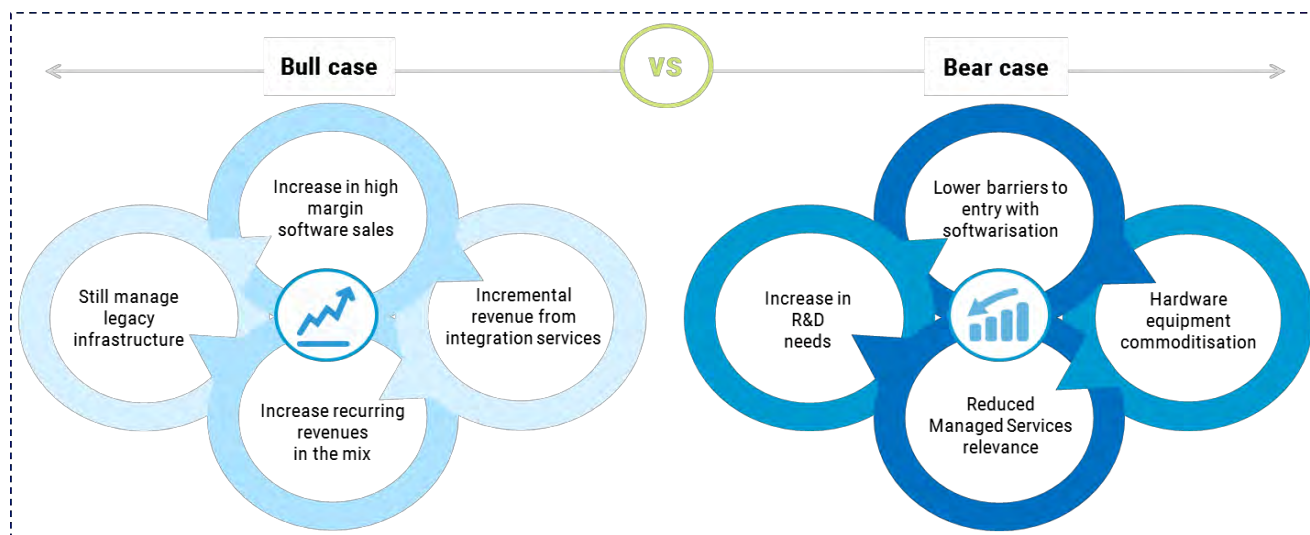
- **However, different telcos are at different stages of implementation**, with some having made greater progress on the purest form(s) of virtualisation, whereas others have made a less ambitious trajectory and/or adopt a hybrid approach.
- **Rakuten in Japan has stated it will launch its network in Oct 2019 on 4G, with 5G launch in 1H20. This is a full end-to-end virtualisation of wireless.** Importantly, we note that the CEO of Dish in the US has stated on the company's 2Q19 results call that it expects to follow a technological approach which is even more extensive in its utilisation of wireless softwarisation which Rakuten is pioneering. He also highlighted key advantages of this type of approach in terms of capex and opex (detailed takeaways in Exhibit 30). We note that most US telcos are working on virtualising the core as well RAN. Our work also suggests Korean telcos could take a relatively similar approach.
- **As such, our industry discussions suggest that the US, Korea and Japan are leading in deployments for testing and trials for virtualized wireless networks (albeit they are doing this to varying degrees). Meanwhile, some geographies such as Europe and China appear to be less advanced. That said, we note Three UK is pursuing a virtualised approach to wireless, but this appears to have a greater emphasis on virtualising the core (and non real-time functions).**
- We note that there is a burgeoning vendor ecosystem. Key players currently comprise Nokia, Ericsson, NEC, Cisco, Mavenir and Altiostar, among others.

**Implications for equipment vendors: Potential risks and opportunities**

- **We believe the shift from selling (and servicing) specialised wireless equipment hardware to providing software that runs on more standardised boxes (provided by other OEMs in the datacentre) could pose challenges to existing wireless equipment vendors** if they fail to position themselves appropriately.

- **We believe the real-time functions (i.e., DU) would need to be run on a FPGA SoC or a GPU within the edge cloud server.** This would still be more standardized/centralized than a traditional network, where processing occurs on specialised hardware on each base station.

**Exhibit 11: RAN virtualisation could increase high-margin software sales but could also lead to hardware commoditisation**  
Bull and bear case for equipment vendors



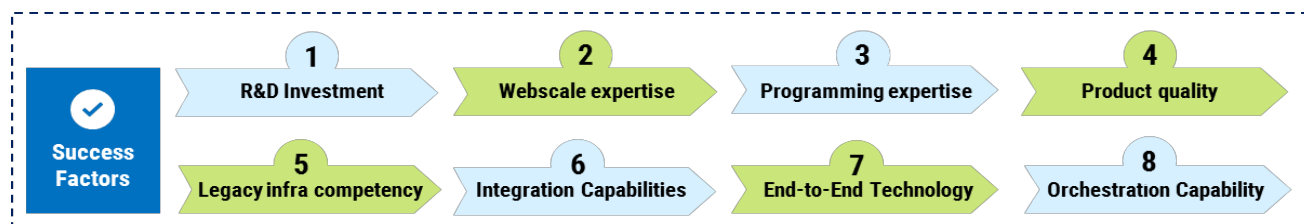
Source: Company data, Goldman Sachs Global Investment Research

- **Whereas base stations under the old model could be sold for tens of thousands of US\$, to the extent that real-time functionality migrates to the edge cloud server/datacentre, this by definition reduces the hardware value that accrues to equipment vendors.** As such, it would be hard to justify such a high price if part of the processing is happening on non-specialised hardware (that is not provided by the equipment vendor).
- **Moreover, it creates risks of commoditisation, given that the new approach effectively decouples the provision of software functionality from hardware provision.** In other words, software from one vendor (not necessarily even a traditional wireless base station vendor) can run on totally different hardware from another vendor.
- **We believe decoupling of the provisions of software and hardware by different vendors could be one of the biggest challenges for existing vendors, and could provide opportunities for the smaller vendors like NEC.** We argue this dynamic a) lowers barriers to entry for networking technology; b) reduces the competitive moat represented by the hardware installed base (and could allow new smaller vendors to take share); and c) could make it harder for equipment vendors to continue to charge high prices for equipment solutions (unless they can demonstrate they have market leading software).

- **Fundamentally a significant portion of current hardware sales - from an equipment vendor perspective - may well need to be compensated for by providing software for virtualising and integrating key network functions and orchestrating various operations.** Thus, success in transitioning to provide such software is key for existing vendors. We believe this puts an emphasis on effective R&D spending, for example, while, on the upside, providing scope for higher profitability (given software is more margin rich than hardware). We believe the transition will not only involve incremental R&D spend, but a change in skillsets, e.g., programming language expertise, which could require a change of approach (and potentially drive acquisitive M&A of software companies).

#### Exhibit 12: We believe there are multiple success factors for equipment vendors

Key success factors for equipment vendors



Source: Company data, Goldman Sachs Global Investment Research

- **We note also that people-heavy services (e.g., Managed Services where a vendor runs a telco's network) represent a high degree of sales (e.g., 12%/25% at Ericsson/Nokia in 2018) and could be under threat given the greater degree of automation of the network (thus obviating the need for such a high degree of labour-intensive work in running the networks).** That said, this will to some extent be balanced by the shift to virtualisation involving incremental integration services opportunities.
- **Thus, we lay out a roadmap for investors as well as key factors to monitor in weighing up vendors' scope to improve profitability** (by monetising software) and compensate for risks from hardware commoditisation (see Exhibit 9).
- We reiterate our Sell on **Nokia**; while noting the company's proactive approach in this area, we nevertheless see **11%/18% incremental upside/downside to our 12m PT in our most positive/negative scenario**. While we remain Buy rated on **Ericsson (on Conviction List)** in the context of near-term 5G driven cyclical demand improvement, **our analysis implies 4%/19% incremental upside/downside respectively**. In a separate note last week, we also upgraded **Rakuten** to Buy (see [here](#)) and analyse implications for **Buy-rated NEC (on Conviction List), Cisco and ZTE**.

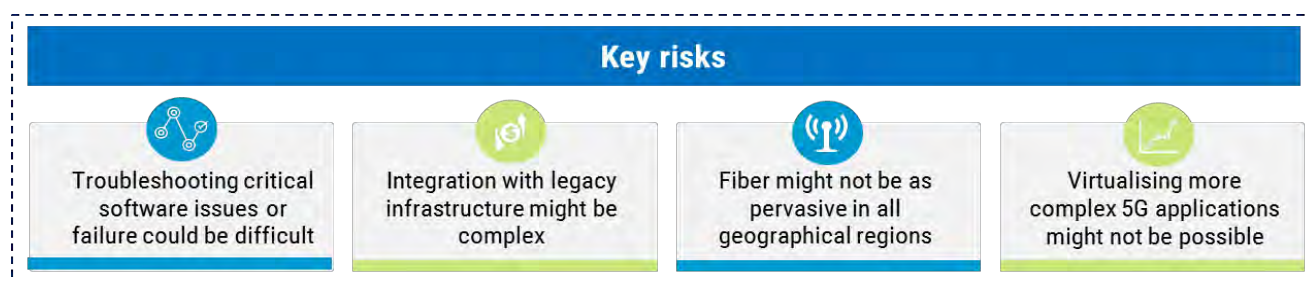


## The Cynic's View

There are various reasons why a shift to a virtualised approach could be less broad-based on a global scale than we expect. As detailed below, key risks to this trend include difficulties to resolve critical software issues, complexities when integrating with legacy technology, limited fiber in geographical regions, and difficulties in virtualising more complex 5G applications.

- Firstly, the software-based nature of a virtualised network could cause issues.
- Secondly, legacy integration poses difficulties as opposed to a greenfield build.
- Thirdly, lack of access to fiber could limit softwarisation scope. That said, we note efforts in the industry are underway to deliver technological solutions that will enable fronthaul for virtualisation more efficiently on fixed-connectivity other than fiber. Thus in regions where fiber is not as pervasive (and/or is costly), operators could deploy virtualised RAN. We note BT Labs, ADVA and Mavenir tested working on a similar solution in Feb 2018, and Altiostar explicitly follows this approach.
- Fourth, some 5G applications may not have softwarisation potential. Furthermore, our industry discussions suggest some vendors believe (at least in the near term) that for some functions in the network, performance could be better on specialised hardware. However, we believe in the long term, progress could be made in this direction.

**Exhibit 13: Key risks related to transformation to fully virtualised networks**



Source: Goldman Sachs Global Investment Research

- Also, there have been debates around the performance of the network with multiple equipment vendors participating in the deployment.
- Traditional networks have different types of pre-installed equipment on the pre-existing cell sites vs no legacy hardware for the new ground up networks. Therefore, you can softwarise everything from the beginning in the case of a greenfield network which can lead to cost savings. Thus, the benefits from softwarisation may not be as great for a traditional network shifting to softwarisation vs. a greenfield network.
- Additionally, given the pre-existing networks will already have built cell sites for 4G including site acquisition cost and backhaul cost, there will not be as much of a benefit from the lower site costs as would be seen on a greenfield network because the telcos would already have invested some costs in the pre-existing 4G site. Moreover, assuming 4G equipment has already been built out, this would remain on the cell site even if new 5G baseband equipment will be centralized/virtualised.

Thus, the related cost savings, e.g., site leasing, might be limited. Alternatively, one could switch out the pre-existing baseband but this could involve substantial costs. That said, in the long run, as the technology improves and the costs increase as function of Moore's law, we believe that introducing new virtualised technology will become more economical.

- Finally, Rakuten's fully virtualized wireless networks are yet to launch and hence are unproven. Furthermore, Rakuten's launch of its 4G network will reportedly initially be on a smaller scale geographically than originally envisaged, albeit we note this is largely due to company-specific factors, e.g., labour shortages, rather than permanent technological show stoppers.

### Valuation of key impacted companies

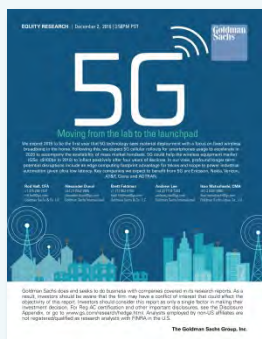
#### Exhibit 14: Valuation multiples

Prices as of Wednesday 28 August close

Company Name	Rating	Pricing Currency	Last Closing Price	P/E		EV/EBITDA		EBITDA Margin	
				CY2019E	CY2020E	CY2019E	CY2020E	CY2019E	CY2020E
Ericsson	Buy*	SEK	78.64	24.1x	14.7x	8.0x	6.8x	14.2%	16.2%
Nokia	Sell	EUR	4.52	21.6x	15.8x	8.8x	7.9x	11.7%	12.9%
ZTE Corp.	Buy	HKD	20.60	15.6x	12.4x	7.6x	7.2x	11.3%	9.9%
Samsung Electronics	Buy	KRW	43,950.00	14.0x	10.6x	3.8x	3.2x	24.0%	27.4%
NEC	Buy	JPY	4,540.00	15.6x	12.2x	7.3x	6.3x	7.4%	8.3%
Fujitsu	Neutral	JPY	8,528.00	15.1x	12.8x	10.2x	8.6x	4.4%	5.2%
Rakuten	Buy	JPY	932.00	14.7x	25.4x	6.3x	7.5x	20.7%	15.4%
<b>Mean</b>				<b>17.7x</b>	<b>13.1x</b>	<b>7.6x</b>	<b>6.7x</b>	<b>12.2%</b>	<b>13.3%</b>

Source: Datastream, Goldman Sachs Global Investment Research

## RELATED RESEARCH ON 5G

**5G: Moving from the lab to the launchpad**

Dec 2, 2018

We expect 2019 to be the first year that 5G technology sees material deployment with a focus on fixed wireless broadband in the home. Following this, we expect 5G cellular rollouts for smartphones usage to accelerate in 2020 to accompany the availability of mass market handsets. 5G could help the wireless equipment market (GSe: c\$100bn in 2018) to inflect positively after four years of declines. In our view, profound longer term potential disruptions include an edge computing footprint advantage for telcos and scope to power industrial automation given ultra low latency.

**Shedding light on Dynamic Spectrum Sharing - a smoother upgrade path to 5G?**

July 1, 2019

Dynamic Spectrum Sharing enables co-existence of 4G and 5G data traffic on one chunk of spectrum as opposed to requiring dedicated chunks for 4G and 5G. Inside, we analyse the advantages (and challenges) of DSS, including a more efficient use of spectrum which can help drive a significant increase in capacity.

**Is there scope for long-term share shifts in a 5G world?**

Apr 15, 2019

Developments in the \$100bn wireless infrastructure market suggest potential for longer-term share shifts as 5G, the new generation of technology, rolls out.

**Greater China Technology: 5G connecting the future; launching on 35 stocks**

May 7, 2019

We expect the global migration to 5G cellular technology to be a key growth driver for the Greater China Technology space. Although 5G revenues are likely to be low early on, we expect the network upgrade to drive a smartphone replacement cycle in 2020-21E and a new growth phase for semiconductors and telecom equipment.

**Ericsson: Raising estimates on 5G traction and product strength; reiterate Buy**

Apr 15, 2019

Our more positive view on wireless market growth, competitive positioning, and self help leads us to raise estimates.

**Also read:** Ericsson: Networks solid, self-help on track; reiterate Buy, add to Conviction List (July 29, 2019)

**Nokia: Lowering Networks and Patents estimates; down to Sell**

Apr 15, 2019

We see Nokia as a leader in the CommTech space, but downgrade the shares to Sell in light of 2% outperformance in the last 6 months, while SME Direkt consensus EPS has been revised down 44% over that period.

**Visit the 5G page on the GS Research portal for more >**

## Summarised single stock implications



**Price Target: EUR 4.1 | Upside to PT: -7.6% | 2020E P/E: 15.6x | 2020E EV/EBITDA: 7.7x | 2020E EBITDA Margin: 12.9%**

- Nokia provides wireless (c.50% revenue exposure) and fixed-line networking solutions to telcos.
- While we believe there are longer-term risks due to wireless virtualisation (50% of revenues could potentially be impacted), Nokia has been actively making progress in this space and it has been supplying hardware equipment and software to Rakuten, validating its near-term solid position in this domain. That said, we argue Ericsson could be better placed to invest longer term given higher gross margins, cost flexibility and FCF generation (on our estimates). Our analysis implies 11%/18% incremental upside/downside (vs our current 12m PT) in our most positive/negative scenario and a 10%-20% impact on 2021-23 EBIT in a downside scenario and 4%-8% impact in an upside case.
- We remain Sell on Nokia as we continue to see short-term risks to software/hardware technical progress on traditional base stations in the coming quarters. We note NOK is trading at a c20% premium vs Ericsson on 2020E EV/EBITDA (ex-restructuring), despite the fact that ERIC 2020 EBIT/Gross margins ex-patents were 10.3%/35.9% vs NOK at 5.7%/35.1%.



**Price Target: SEK 108 | Upside to PT: +44.3% | 2020E P/E: 14x | 2020E EV/EBITDA: 6.5x | 2020E EBITDA Margin: 16.2%**

- Ericsson offers hardware infrastructure (i.e. base stations), software and related services for wireless networks. It is not involved in fixed line.
- While we are positive on Ericsson on 5G cyclical demand improvement and self-help, we believe it will need, in the mid term, to focus on key milestones related to network virtualisation given 90% of its revenues could potentially be impacted. We note solid recent progress on traditional 5G hardware. Our analysis implies 4%/19% incremental upside/downside (vs our current 12m PT) in our most positive/negative scenario and a 10%-26% impact on 2021-23 EBIT in a downside scenario and 4%-7% impact in an upside case.
- We remain Buy rated (on CL) on Ericsson in the context of near-term 5G demand, share gains and self-help. We note Nokia trades at a c20% premium to Ericsson on 2020E EV/EBITDA, despite our view that Ericsson is better positioned to benefit from 5G and potential upside skews from China vendor share shift.



**Price Target: HKD 35 | Upside to PT: +75.9% | 2020E P/E: 2020E 12.1x | 2020E EV/EBITDA: 7x | 2020E EBITDA Margin: 9.9%**

- ZTE is a global telecom network maker providing wireless, optical transmission, data telecoms gear and telecoms software.
- We believe 50% of its revenues could potentially be impacted from wireless network virtualisation and that the company will need to navigate this transition. However, ZTE has announced certain activities related to virtualisation. For example, in May 2017, ZTE and Banglalink commercialised their virtual subscriber data management platform in Bangladesh, migrating 60 mn legacy users over to the new software.
- We are constructive on ZTE given the structural growth of 5G upcycle and the company is a key telecom equipment vendor with 30% wireless market share in China.



**Price Target: JPY 7,650 | Upside to PT: -6.6% | 2020E P/E: 12.3x | 2020E EV/EBITDA: 8.3x | 2020E EBITDA Margin: 5.2%**

- Fujitsu (within the System Platforms business segment) provides network products to telecom carriers including mobile infrastructure.
- We note Fujitsu announced a partnership with Ericsson in Oct 2018, which we believe will help in reducing the R&D burden from the functional Central Unit/Distributed Unit (CU/DU) split in 5G RAN (when it is virtualised). Currently, Fujitsu is affected by limited investment by carriers.
- We remain Neutral rated on Fujitsu with our 12-month target price of ¥7,650 based on a P/B of about 1.2x, derived from P/B-ROE correlation, and the midpoint of our FY3/20-FY3/21 estimates.





**Price Target: USD 56 | Upside to PT: +19.5% | 2020E P/E: 13.9x | 2020E EV/EBITDA: 10.2x | 2020E EBITDA Margin: 33.8%**

- Cisco is an American multinational technology firm, manufacturing networking technology serving both enterprise and telecommunications customers, as well as other IT infrastructure products such as servers, hyperconverged infrastructure, security, collaboration tools etc.
- Given that Cisco participates more on the fixed line (through its routers, optical systems, switches etc.) than RAN equipment/services side, we believe this trend towards wireless network virtualisation could be an incremental opportunity. Cisco's technology in relation to softwarisation is used by Rakuten.
- We remain Buy on Cisco, driven by the group's fundamentals looking out for the next 12-18 months as we expect the Catalyst 9K cycle to act as an idiosyncratic positive driver of earnings vs. the wider enterprise IT environment.



**Price Target: JPY 1,400 | Upside to PT: +50.2% | 2020E P/E: 25.4x | 2020E EV/EBITDA: 7.5x | 2020E EBITDA Margin: 15.4%**

- Rakuten Mobile Network (owned by Rakuten Inc., an internet services company), is the newest mobile network operator in Japan and has been building a virtualised wireless network. The company is expected to launch virtualised 4G network in Oct, 2019, with 5G to follow in June 2020.
- We believe that the value of the telecom business will depend on subscriber numbers, acquisition cost, roaming costs, and the need for additional investments over the medium term rather than at the time of launch. As such, we see the fact that it is taking a cautious approach in launching its services as a positive.
- We upgrade Rakuten to Buy; while our call is mainly based on valuation, we argue that given the c\$5bn-\$6bn of capex Rakuten is investing there is a reasonable chance its greenfield network can cover the vast majority of Japan. We believe the shares are pricing in the worst-case scenario regarding efficacy of the network, while we acknowledge the network has yet to launch. That said, given the significant investment and innovative technology approach we believe the company could be successful in this venture.



**Price Target: JPY 5,300 | Upside to PT: +15.2% | 2020E P/E: 12.3x | 2020E EV/EBITDA: 6.4x | 2020E EBITDA Margin: 8.3%**

- NEC engages in providing information technology (IT) and network technologies globally. The company's products and services include systems integration, maintenance and support, outsourcing/cloud services and system equipment.
- NEC stands to benefit from virtualisation, as a decoupling of software and hardware provisions could present additional opportunities for vendors like NEC. We note NEC is also co-operating with Rakuten to develop a 3.7 GHz massive MIMO 5G Antenna radio unit. NEC is offering a traditional end-to-end Billing Support system and its wholly owned subsidiary Netcracker is supplying an Operating Support System (OSS) to support Rakuten's mobile network operator launch and subsequent operations.
- We remain Buy (on CL) on NEC given the scope to increase sales in the security business and in the OSS/BSS business, which is mainly a part of Netcracker.



**Price Target: KRW 57,000 | Upside to PT: +29.1% | 2020E P/E: 10.7x | 2020E EV/EBITDA: 3.2x | 2020E EBITDA Margin: 27.4%**

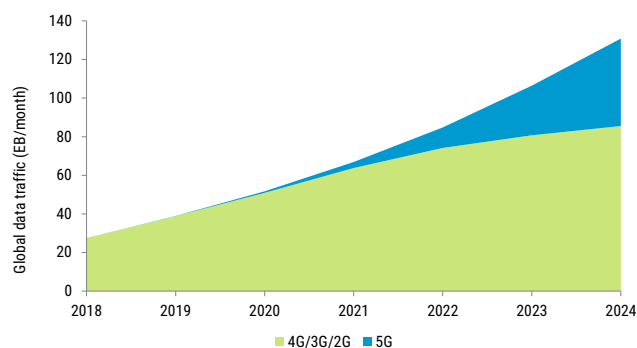
- Samsung has a Networks business which provides equipment used for building 4G/5G networks. It is focused on products related to mmWave spectrum.
- We expect <5% revenue to be potentially impacted from the shift to virtualised wireless network. Samsung and SK Telecom completed the world's first 5G next-generation core trial in June 2018, featuring virtual network functions based on 3GPP release 15 standards and network slicing.
- We remain Buy rated on Samsung and we believe the company has scope to achieve 10% wireless market share in coming years (vs 5% today). While Networking is <5% of group revenues, this could be a fast-growing revenue stream.

## Softwarisation shifts processing to datacentre and automates network

- **While there has been a trend towards virtualisation in the context of the fixed-line part of the network, there has been a greater degree of scepticism as to its applicability to the wireless realm.** In wireless networks today, processing takes place on specialised hardware on the cell site/tower; however, we see the beginning of a trend towards **shifting base-band processing into an edge cloud server/datacentre away from the cell site to be run on a more standardised hardware.**
- We note the **upcoming launch of Rakuten's wireless network in Japan** (in October), which radically redesigns the network structure in this direction, and increasing efforts by established telcos to pursue similar approaches. Our discussions with industry participants suggest **6-12 telcos are working on various approaches to virtualisation.**
- Thus, while it was previously thought virtualisation of network equipment would predominantly be limited to the fixed-line domain, we argue that **recent developments suggest meaningful scope for cloudification of both real-time critical and non-real time functions in wireless networks in the long run.**

**Exhibit 15: Ericsson expects data traffic to grow at c.30% pa in 2018-24**

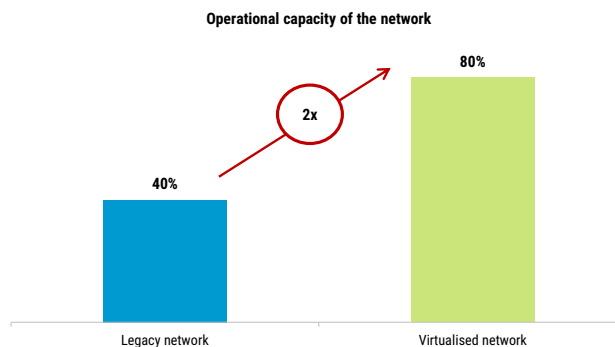
Global data traffic (Eb/month)



Source: Ericsson

**Exhibit 16: Virtualised networks run at high utilization which saves upfront capex**

Illustrative exhibit of capacity utilization

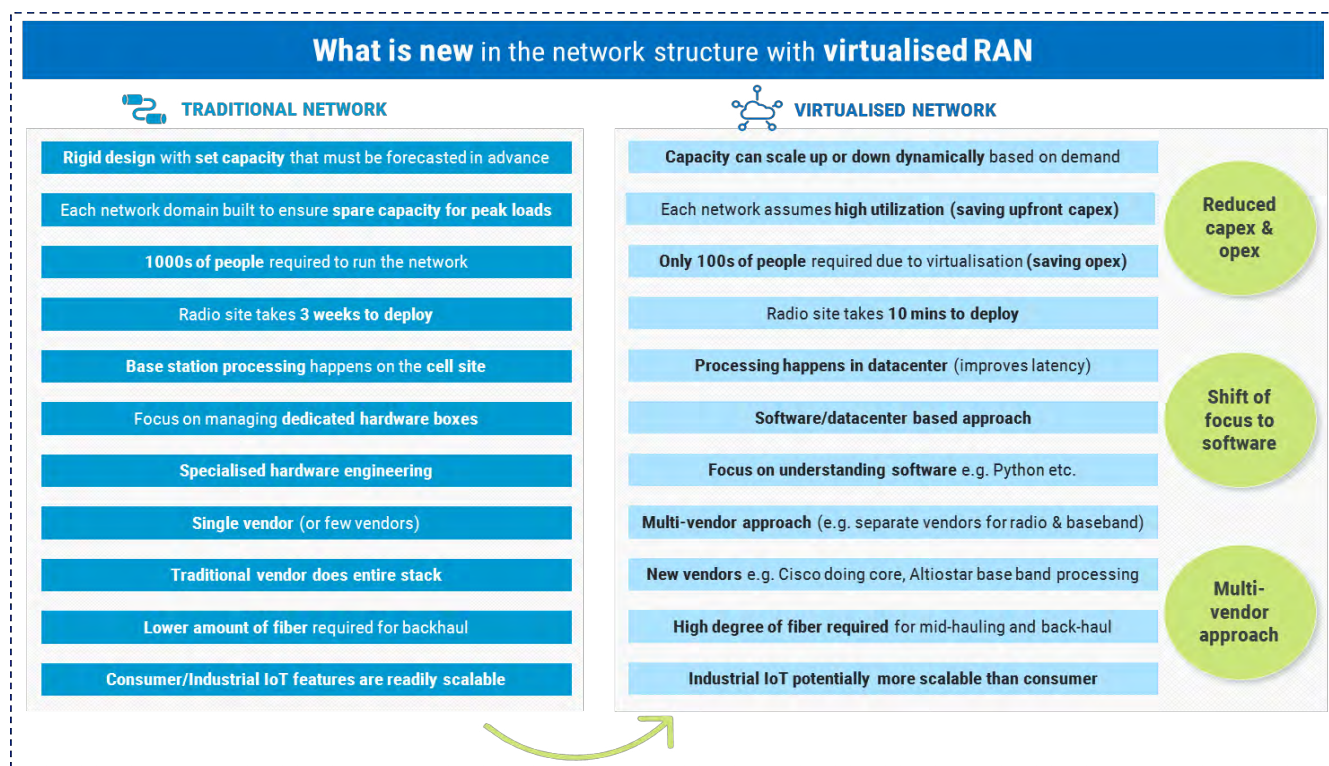


Source: Company data

- **New software approaches associated with virtualisation offer scope meaningfully to reduce capex.** In particular, that being pursued by Rakuten envisages most areas of the network being run at or near full capacity, with the ability to dynamically divert large amounts of network resources from other areas to those where spikes in traffic occur. This contrasts with the traditional approach, where such flexible capacity allocation is not possible and most domains of the network are run at a much lower capacity utilisation level.

### Exhibit 17: Softwarisation of the RAN would help telcos save cost as processing no longer takes place on specialised hardware, capacity is scaled dynamically and networks are highly automated

Characteristics of the virtualised network vs. a traditional network



Source: Company data, Goldman Sachs Global Investment Research

- Moreover, a key tenet of the new approach is that human intervention in running the network will be reduced to an absolute minimum, substituted with automation. We argue **this can have scope to reduce the opex involved in running telco networks, which we believe is significant given that data growth continues at 30%+ per year.**
- Industry participants have suggested **c.50%/c.35% capex/opex savings vs. a traditional network.**

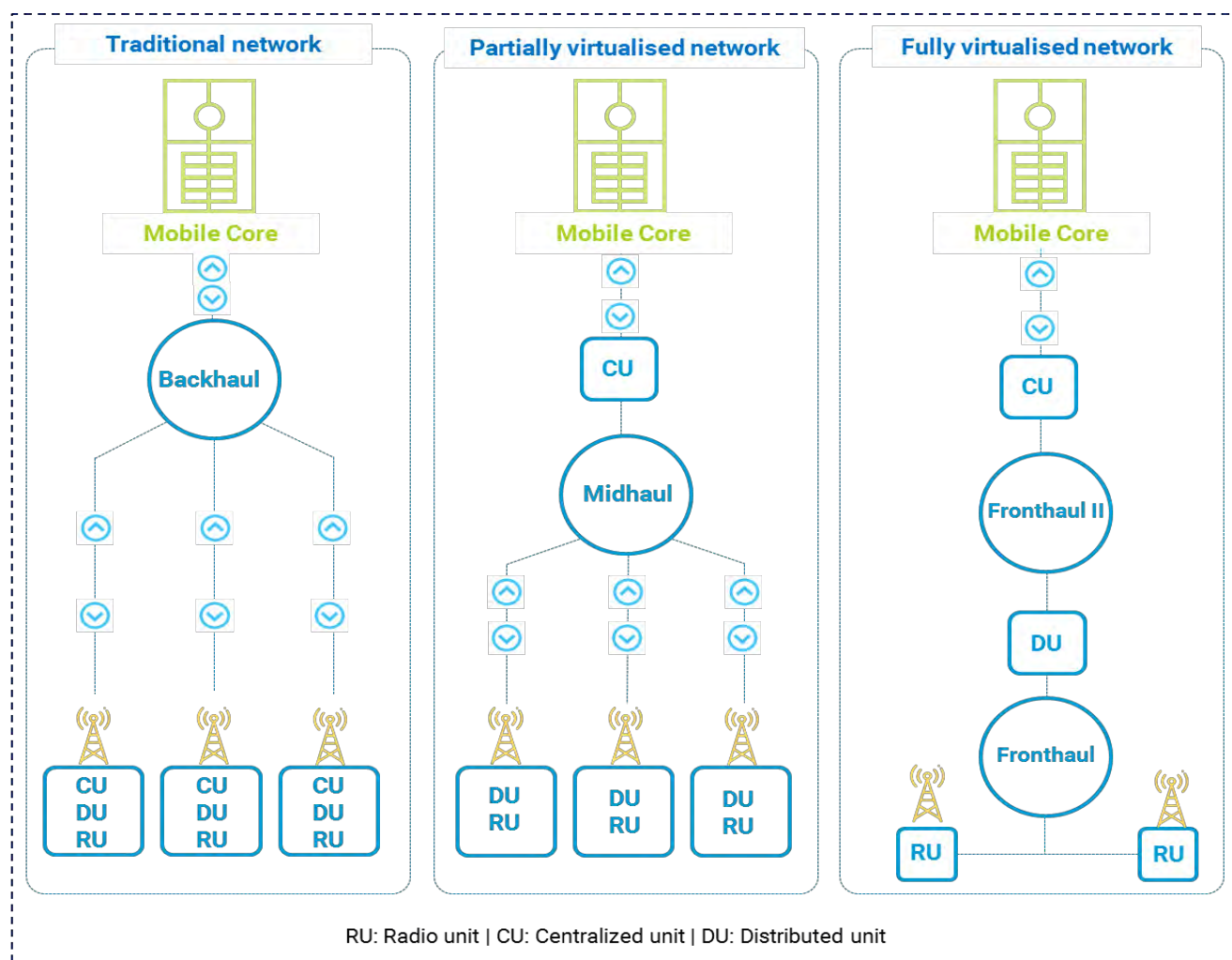


## New network structure allows faster deployment; frees up tower space

- In basic terms, the shift to a virtualised approach involves the antenna and radio unit of the base station remaining on the tower, but with its key processing elements moving to the edge cloud server/datacentre away from the cell site. The non-real time functions (i.e. Centralised Unit processes) can be virtualised in a datacentre, while the real-time functions (i.e. Distributed Unit ) are shifted to an edge cloud server (between the datacentre and the cell site). Thus, the base band unit no longer remains on the cell site/tower.

**Exhibit 18: New fully virtualised network structure moves base band processing (Centralized Unit and Distributed Unit network elements) to the datacentre/edge cloud server, leaving only radio unit and antennas at tower site**

Schematic diagram of network structure (traditional network vs. virtualised CU vs. virtualised CU/DU)



Source: Company data, Goldman Sachs Global Investment Research

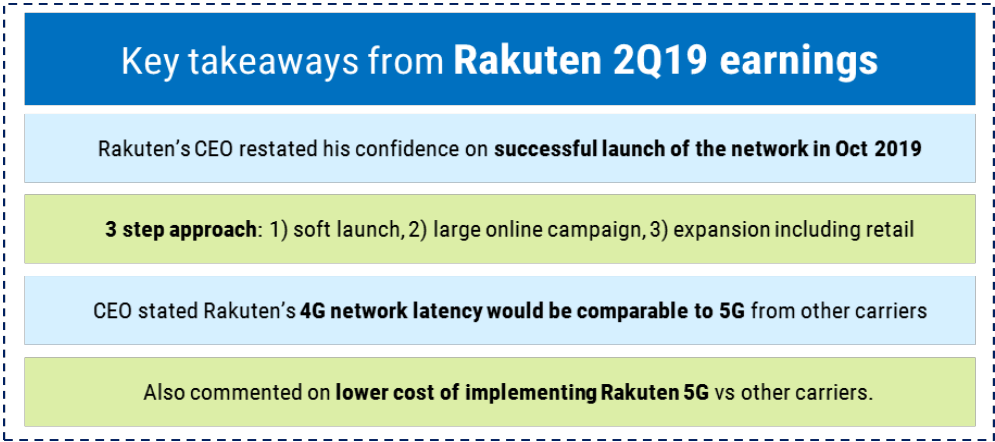
- As such, this puts increased emphasis on having a strong fixed-line backhaul network to connect up antennae with the domains in the network where processing now occurs (i.e. in the datacentre). We note the Distributed Unit (DU) can be on an edge cloud server up to 30km away from the cell site (vs processing of real-time functions being done on the base station in a traditional network), and the



Centralised Unit (CU) can be virtualised in a datacentre up to 200km away from the cell site. Thus, it offers a significantly higher scope of centralizing the processing of data from a large number of base stations, rather than each base station doing its own processing. This drives energy and other cost savings.

- **While it was previously thought that only functions *not* required to be executed in real time could be virtualised (e.g. subscriber management and provisioning), Rakuten’s implementation involves real-time specialised functions being executed away from the base station.** Thus while it was previously thought that non-critical functions would be executed by a centralised unit (CU) that would sit in the datacentre, with a distributed unit (DU) at the cell site, Rakuten’s implementation effectively involves the shifting both CU and DU away from the cell site.

Exhibit 19: Key takeaways from Rakuten’s 2019 earnings call



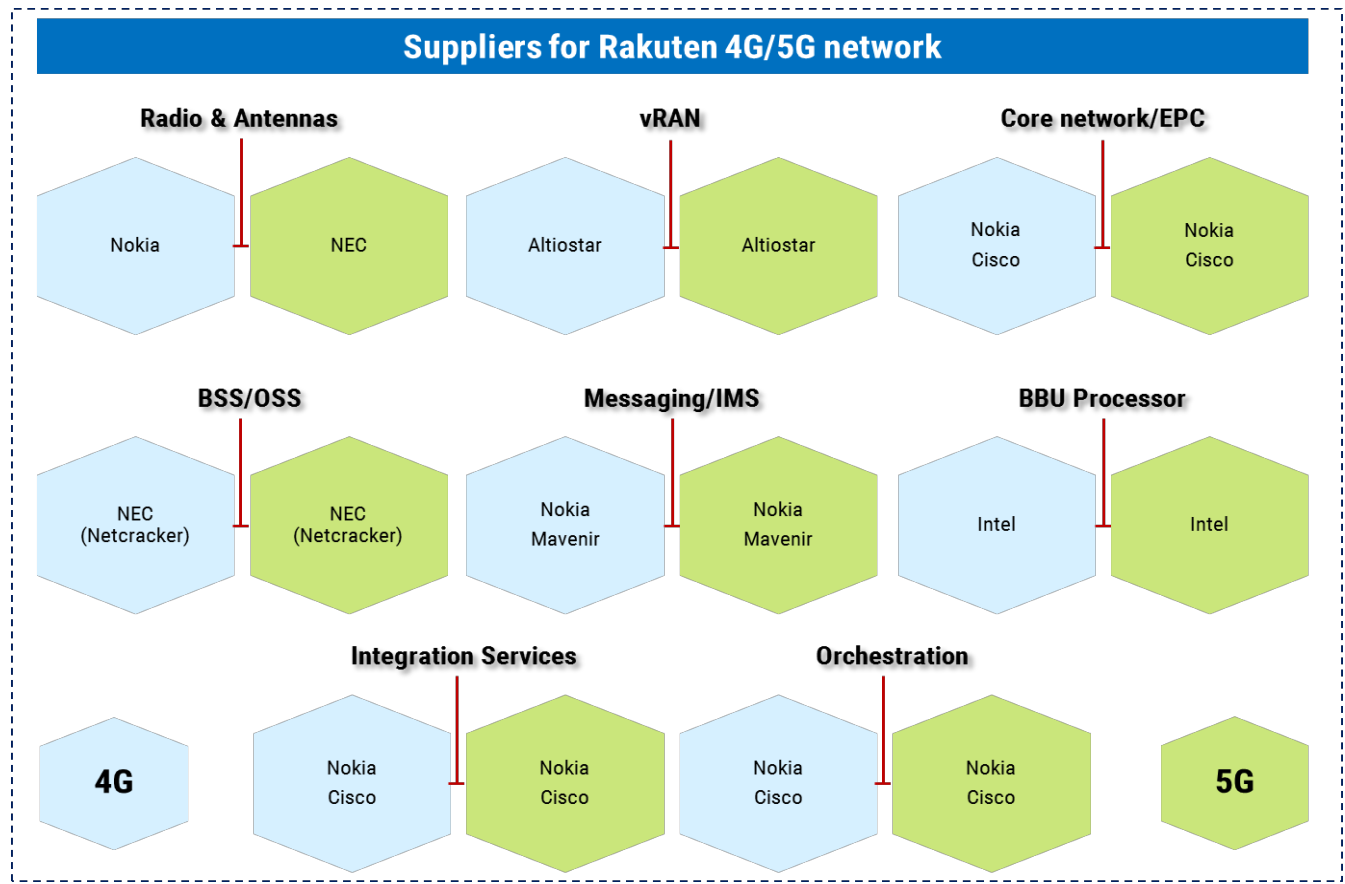
Source: Company data

- **Given that the cell towers will now essentially only need to accommodate the antenna and radio, we believe this will allow more antennas to be accommodated. This would be important in a 5G world (as innovations such as Massive MIMO require a significant increase in the number of antennas).** This could accelerate the extent to which more advanced 5G functions are possible mid-term, as techniques such as beamforming are utilised. That said, we note in the long term Massive MIMO could involve more processing on the cell site (radio unit) which may entail more processing costs (partly offsetting softwarisation benefits).

# Rakuten plans to launch 4G network in Oct 2019; 5G to follow in 2020

- **Internet services company Rakuten (which has strong positions in e-commerce and financial technology in Japan) plans, through its subsidiary Rakuten Mobile Network (RMN) to launch a nationwide network in Japan in October 2019**, with an innovative architecture that allows for full virtualisation according to the principles described above.
- **This will be the world’s first cloudified network, with full virtualisation from radio access network (RAN) to core with end-to-end automation for both network and services.** Radio access will initially be 4G LTE (macro and small cells) and Wi-Fi, with **5G to follow by June 2020.**

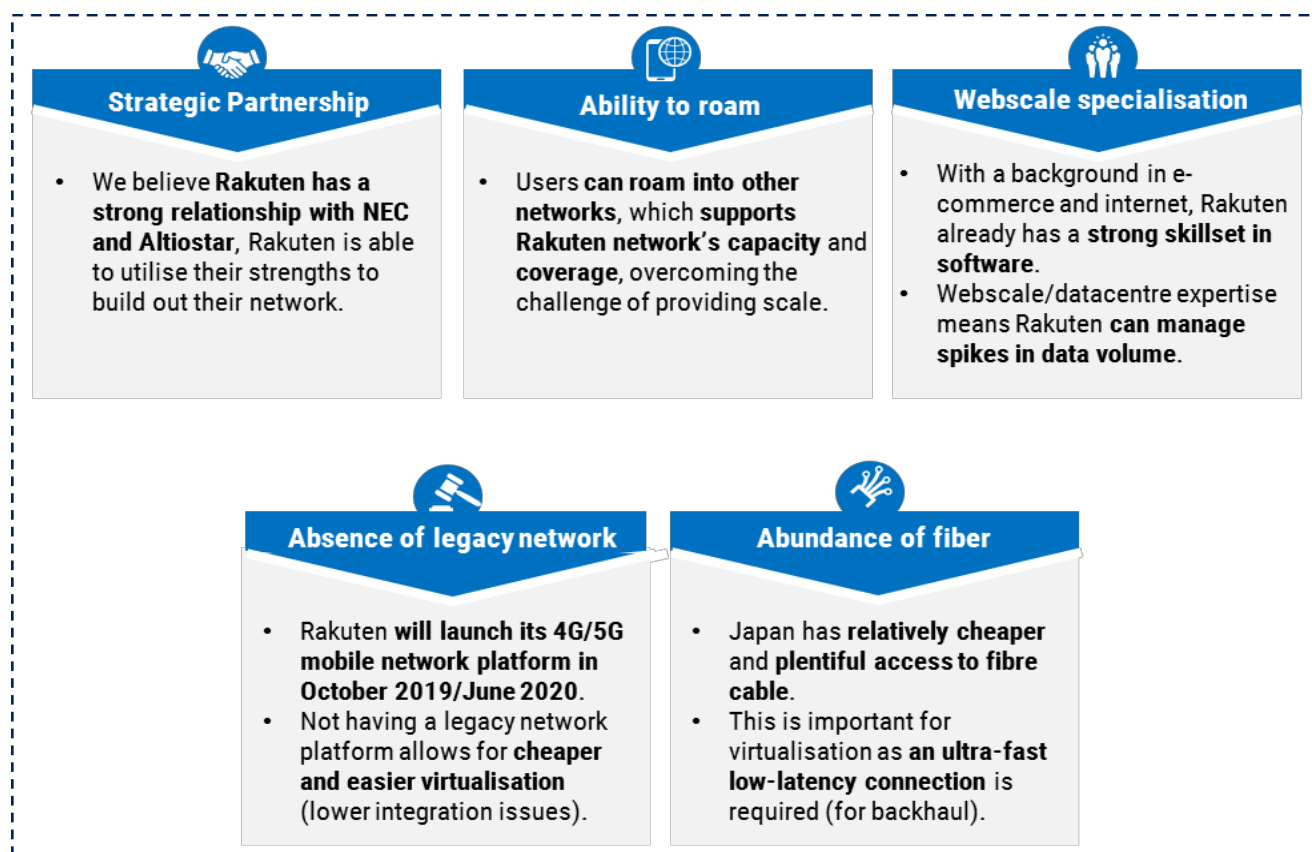
**Exhibit 20: Overview of key vendors for Rakuten network**  
Suppliers for Rakuten 4G network and potential key vendors for 5G network



Source: Company data, Goldman Sachs Global Investment Research

- **Key technology bricks include: virtualised RAN** (from Altiostar), **virtualised Evolved Packet Core** (from Cisco), **IMS** (from Nokia and Mavenir), **BSS** (from Netcracker). It will also incorporate virtualised network functions related to security etc. We provide an illustration of potential key vendors for both 4G and 5G on the Rakuten network in Exhibit 19. While the situation is still fluid in terms of final vendors on 5G, we have added potential leading vendors for 5G deployment based on our industry discussions.

**Exhibit 21: We see multiple factors which support Rakuten's ability to offer fully virtualised 4G/LTE and 5G networks**



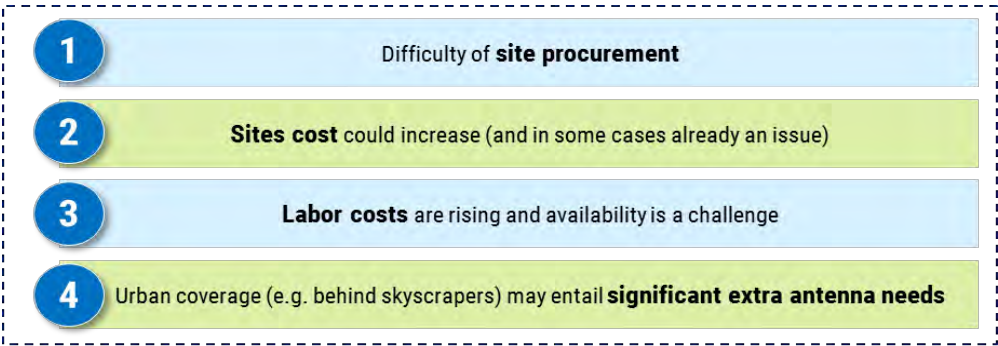
Source: Company data, Goldman Sachs Global Investment Research

- **Our discussions with industry participants suggest that several factors are of significance in facilitating Rakuten's ability to softwareise a network** including the relatively large amount of high quality fiber infrastructure in Japan (allowing for strong responsiveness of the backhaul and hence the network), their partnership with Altiostar (which could give them advantages in terms of understanding vRAN) and their webscale expertise (i.e. advanced capabilities in scaling traffic up and down and managing "bursts" of data in a datacentre context).

- **That said, near term we believe cost advantages of Rakuten’s network should not be overstated vs. other telcos and highlight certain key risk factors.** We note: **1) near-term cost advantages from implementations such as Rakuten’s should not be overstated** given Japan is already virtualizing part of the wireless network (Japanese carriers have been adopting the RRH/C-BBU architecture from 4G, having computer parts located in fewer locations), **2)** we detail bottlenecks that could slow down rollouts such as Rakuten’s and **reduce cost advantages meaningfully (e.g. site procurement).** We note on August 16 the Nikkei reported that the scale of Rakuten’s launch may initially be smaller in October 2019 than originally envisaged, given issues related to labour shortages and wiring capacity (albeit we do not see these as technical show stoppers); and 3) Rakuten’s fully virtualized wireless networks are **yet to launch and hence are unproven.**

**Exhibit 22: We see various potential bottlenecks for Rakuten’s rollout and reasons cost savings may not be as large as expected**

Examples of potential challenges for Rakuten

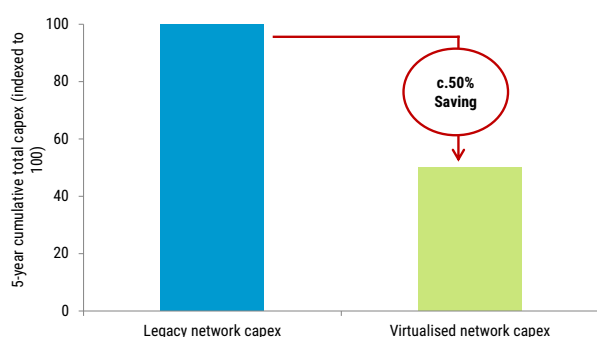


Source: Company data, Goldman Sachs Global Investment Research

## Multiple long-term cost benefits to telcos from softwarisation

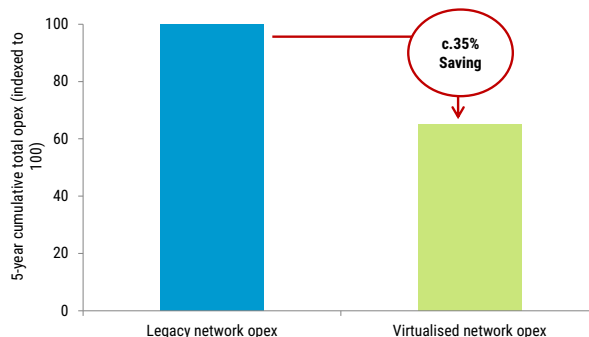
- We see multiple **longer-term** benefits of the new approach, with scope to **meaningfully reduce capex: virtualisation envisages most areas of the network being run at or near full capacity, with the ability to dynamically divert large amounts of network resources from other areas to those where spikes in traffic occur**. This contrasts with the traditional approach, where such flexible capacity allocation is not possible and most domains of the network are run at a much lower capacity utilisation level, in order to accommodate incremental traffic when it occurs. By definition the new approach thus allows for a lower capex outlay for a given amount of overall network capacity.
- Another reason telcos could see reduced capital investment needs is due to the dynamic whereby expensive specialised hardware is replaced by processing taking place on edge cloud server hardware (for DU) and standardised datacentre hardware (for CU). In our view this could make it harder for vendors of traditional hardware to justify as high a price (for each base station). That being said we believe that software that drives network functionality/orchestration will have more value, meaning there will be value for vendors to capture from this (likely with higher margins).
- According to Nokia, virtualisation could lead to **capex savings up to high single-digit to teens** for network operators. Additionally, **opex benefits for operators can be 20%-30%**, resulting in **30%-35% overall cost savings** (assuming end-to-end fixed and wireless implementation), albeit this would be more achievable in the longer term assuming industry manages to softwarise effectively.

**Exhibit 23: Our industry discussions suggest that wireless softwarisation can lead to large capex savings...**



Source: Goldman Sachs Global Investment Research

**Exhibit 24: ...as well as opex savings for telcos in the longer run**



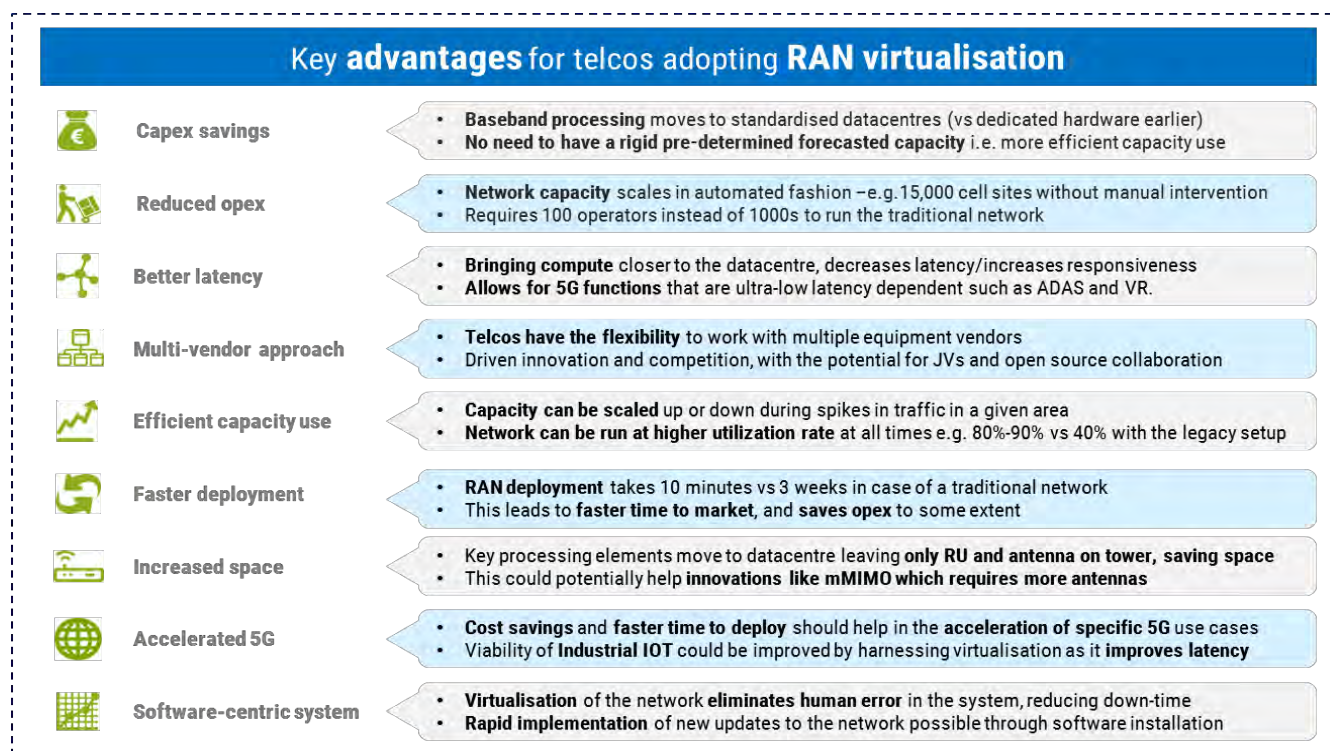
Source: Goldman Sachs Global Investment Research

- Moreover, a key tenet of the new approach is that human intervention in running the network will be reduced to an absolute minimum, substituted with automation. We argue this can have scope to reduce the opex involved in running telco networks, which we believe is significant given that data growth continues at 30%+ per year. Notably, whereas a nationwide wireless network may



require e.g. several thousand people to run it, a fully virtualised one could require only hundreds.

**Exhibit 25: Softwarisation of 5G network will allow telcos to save on opex, upfront capex, and help speed up deployment**  
Key advantages of adopting virtualisation approach for deploying 5G



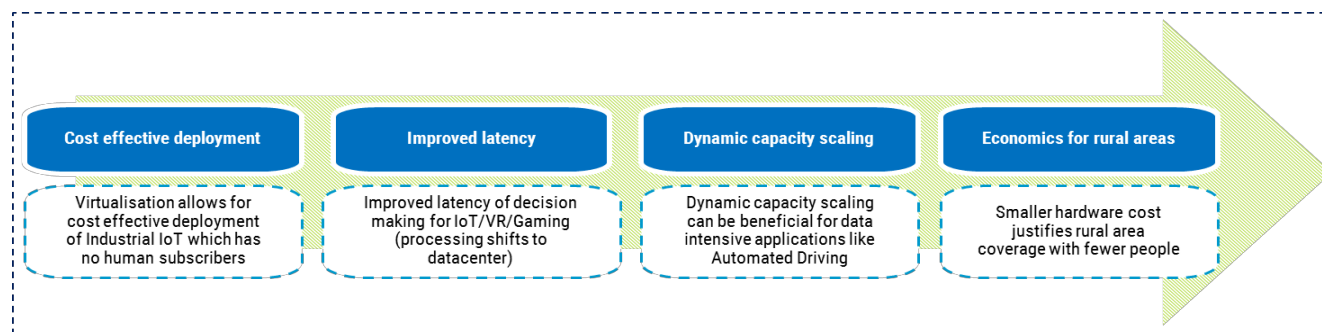
Source: Company data, Goldman Sachs Global Investment Research

- **However, we note that given extra fiber fronthaul/backhaul requirements in some regions, depending upon fiber availability, this could to some degree offset capex savings.** That being said, we still believe more standardised hardware for both the edge cloud server (for DU) and standardised datacentre hardware (for CU) can lead to net capex benefits overall for telcos. Furthermore, **operational cost savings are in our view clear** e.g. energy savings (and *potentially* some space savings on the cell site) from a more centralized processing approach.
- **Other benefits include scope for more rapid cell site deployment (10 mins vs 3 weeks “theoretically” for a traditional network), scope to reduce human error in network management and importantly, potential for greater telcos bargaining power/tech innovation** given the new approach of players like Rakuten/Cisco/Altiostar decouples provision of hardware from provision of software.
- **That said, we note *near-term* cost advantages from implementations such as Rakuten’s should not be overstated** given 1) some other Japanese telcos are already virtualizing part of the wireless network (i.e. CU) e.g. NTT Docomo 2) while the cost of Rakuten using IA servers and Altiostar software may be cheaper than traditional telcos implementation of CU, the efficiency of the CPU utilization may not be significantly different on the CU on the Rakuten implementation vs the approach on traditional networks. However, we believe over time Rakuten’s approach to virtualise DU could yield benefits.

## Softwarisation could help catalyse deployment of 5G use cases long term

- **In our view, softwarisation of the wireless network, i.e. virtualisation and associated cost savings, could potentially help accelerate the application of 5G technology** to use cases such as Industrial IOT.
- **First, given that industrial IOT use cases (e.g. factory automation) do not have a pre-existing large number of consumers to provide an economic underpinning for data provision**, cost effective deployment via virtualised solutions (which help reduce capex/opex needs) may help drive uptake.
- **We expect the Industrial IOT rollout of 5G to happen *after* the initial consumer rollout, and likely be associated with the standalone 5G standard (for Industrial IOT) which has yet to be finalised.** This means that a large scale rollout is more likely to happen in 2022 onwards, as per our report [Global Technology: 5G: Moving from the lab to the launchpad](#), given the need to finalise specific standards and business models. At that point in time, it is possible virtualisation could help accelerate the pace of use case adoption.

**Exhibit 26: Virtualisation can help accelerate the ramp up of 5G longer term**



Source: Company data, Goldman Sachs Global Investment Research

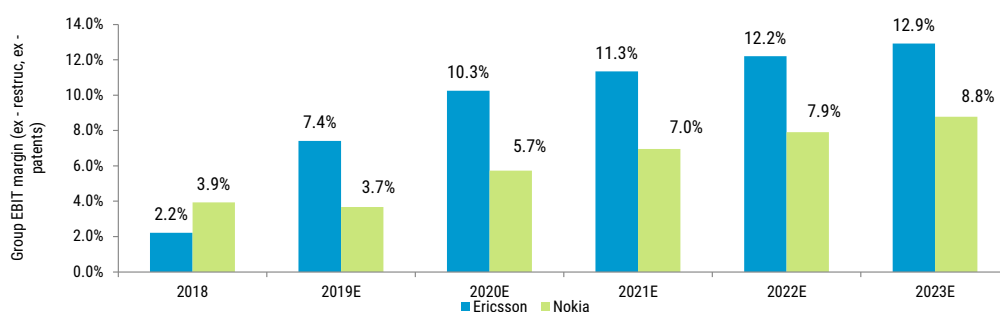
- **Second, we believe that the viability of Industrial IOT could be improved by harnessing virtualisation.** In particular this use case, e.g. in a factory/automated driving setting typically leverages 5G fast connectivity, allied to a collection of extremely large quantities of data from sensors, and real time analysis of this data. Given the proximity of the data to the place where the processing will occur, we believe this will improve latency/speed of decision-making.
- **Third, for use cases such as Automated driving**, where the volume of data collected and sent over the network could potentially be extremely large at certain times of day, **the capability to scale capacity up or down dynamically could be particularly advantageous.**

## Roadmap for broader adoption; challenges/bottlenecks

- **We see challenges for broader, longer-term adoption of a highly virtualised software-centric approach.** We lay out a roadmap for wider telco usage.
- **First, we believe the ecosystem will need to improve software capabilities e.g. programming language knowledge.** Given that the fully virtualised approach aims effectively to eliminate human intervention in running the network, it is reliant on automation via software. While we see clear advantages to this, it could also mean that if there is a software issue that takes time to fix, it could create reputational issues.
- **Second, vendors will need to have the capabilities to integrate the installed footprint of legacy hardware with new/virtualized hardware.** While Rakuten is a greenfield build (from the ground up), other telcos would need to support the installed footprint of legacy hardware.
- **Third, moving processing to the edge cloud server/datacentre is predicated upon having extensive fiber networks in a particular network,** so as to have rapid and reliable backhaul. This may not apply in every region.
- **Fourth, vendors will need to demonstrate sufficient investment capacity.** A shift from the provision of specialized hardware to software requires investments in the context of wireless equipment vendors that are still restructuring. Gross margins and cost structures must be able to accommodate this investment.

**Exhibit 27: Ericsson could be better placed to invest longer term given higher EBIT margins and better cost flexibility vs Nokia**

Group EBIT margin (ex-restructuring, ex-patents)

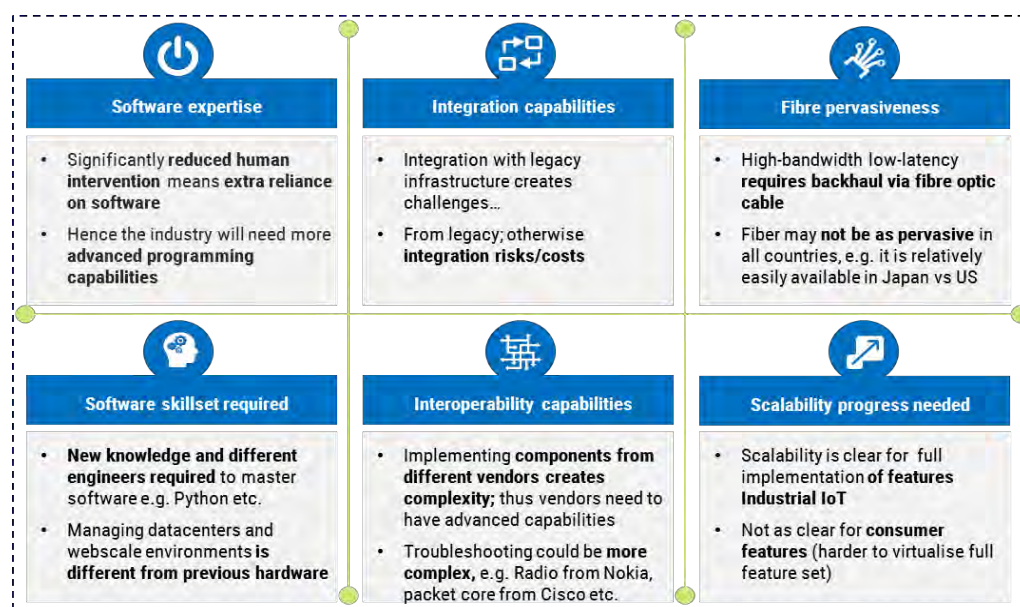


Source: Company data, Goldman Sachs Global Investment Research

- **Finally, as things stand, there is some debate as to the ease with which every 5G application may be virtualised.** For example, some argue that industrial IOT is more apt for virtualisation, given features may be less complex, whereas this may be less so for some consumer use cases.

**Exhibit 28: We lay out a roadmap for broader adoption and see various bottlenecks/challenges**

Roadmap for adoption of virtualised RAN



Source: Company data, Goldman Sachs Global Investment Research

- **We also believe traditional equipment vendors need to understand webscale techniques.** The Rakuten approach involves managing “bursts” of traffic and allocating capacity in the datacenter.
- **Given separation of radios and baseband processing could mean entry of more vendors, hardware standardisation becomes especially important for maximisation of cost benefits.** Thus, we note the industry will need to coalesce around a strategy for hardware standardisation if they want to realise the full cost benefits (so that the industry could open up to multiple vendors).
- **As such, in the near term, decoupling of software and hardware provisions may actually have a bigger impact in terms of cost** than utilization of the datacentre (for non-real time functions) and edge cloud (for real time functions) for telcos.
- **While Rakuten is due to launch its 4G network in Japan in October 2019 and plans to launch its 5G network in 2020, we believe there are various near-term bottlenecks to this implementation as detailed below.** We note 1) **near-term cost advantages from implementations such as Rakuten’s should not be overstated** given Japan is already virtualizing part of the wireless network, 2) we detail bottlenecks that could slow down rollouts such as Rakuten’s and **reduce cost advantages meaningfully (e.g. site procurement)**. We note on August 16 the Nikkei reported that the scale of Rakuten’s launch in October 2019 may initially be smaller than initially envisaged, given issues related to labour shortages and wiring capacity (albeit we do not see these as technical showstoppers). 3) Rakuten’s fully virtualized wireless networks are **yet to launch and hence are unproven**.

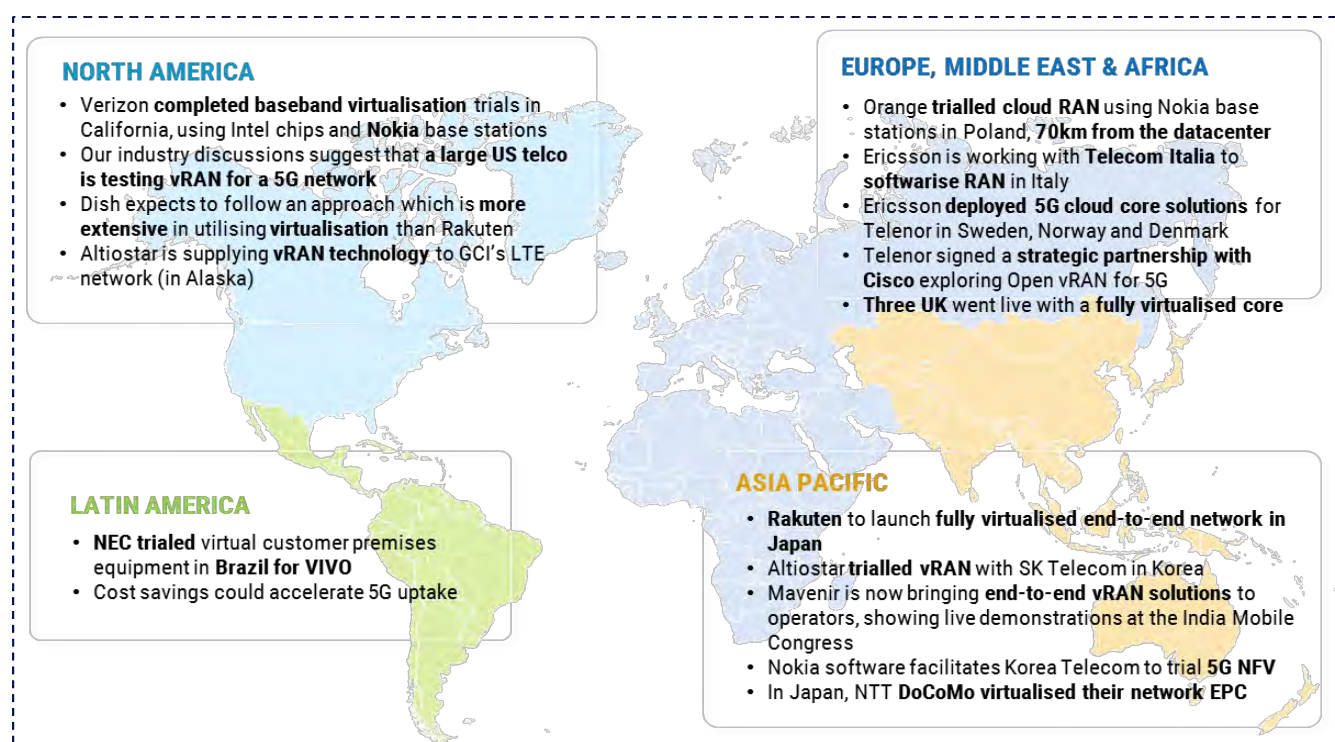


## 6-12 telcos to virtualise RAN aided by a growing vendor ecosystem

- **Our industry discussions suggest 6-12 telcos (aside from Rakuten) are working on** virtualisation of wireless to varying degrees (specifically V-RAN, associated network functions and automation), and we expect them to make significant progress in this space in the next 3-5 years (with players working on greenfield networks expected to be faster vs existing networks).
- **We see a diverse regional approach in shifting to virtualisation of wireless specifically.** That said, we note the direction of travel towards *broader* virtualisation is clear with all vendor discussions with telcos globally typically involving some element of virtualisation (of the core, and often regarding virtualisation of OSS/BSS).

### Exhibit 29: Regional progress on virtualisation

We see a varied picture regionally with fully virtualised network being launched first in Japan



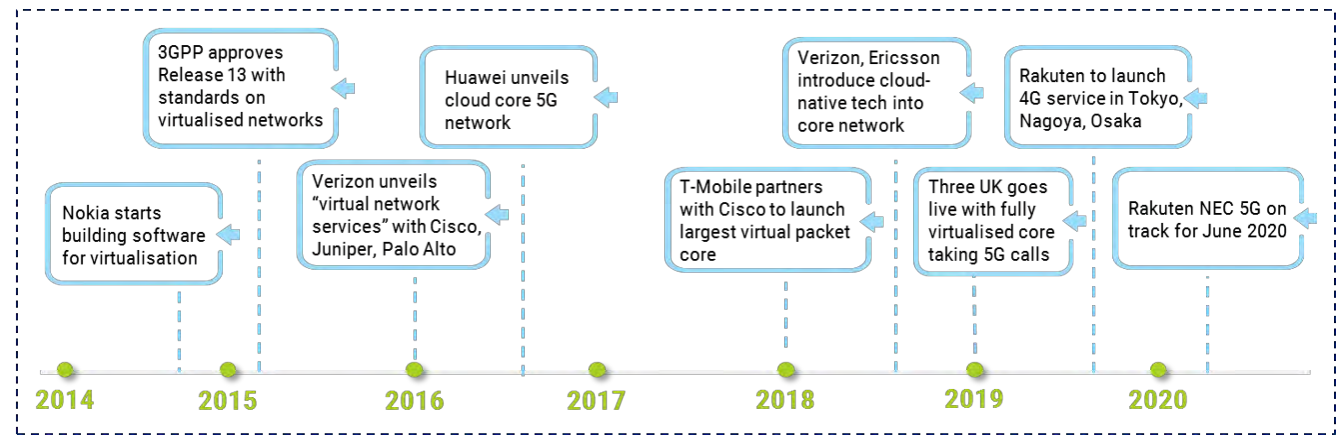
Source: Company data, Goldman Sachs Global Investment Research

- In our view, however, **different telcos in various regions are at different stages of implementation**, with some having made greater progress on the purest form(s) of virtualisation, whereas others have made a less ambitious trajectory and/or adopt a hybrid approach.
- **Rakuten in Japan has stated it will launch its network in October 2019 on 4G, with 5G launch in June 2020. This is a full end-to-end virtualisation of wireless.** Importantly, we note that the CEO of Dish in the US has stated on the company's 2Q19 results call that it expects to follow a technological approach which is even more extensive in its utilisation of wireless virtualisation/softwarisation than that which Rakuten is pioneering. He also highlighted key advantages of this type of approach in terms of capex and opex (detailed takeaways in Exhibit 30). We note



that most US telcos are working on virtualising the core as well RAN. Our work also suggests Korean telcos could take a relatively similar approach, **based on industry discussions.**

**Exhibit 30: We believe there has been significant interest amongst telcos in shifting towards RAN virtualisation**  
Timeline of key events



Source: Company data, Goldman Sachs Global Investment Research

- **As such, our industry discussions suggest that US, Korea and Japan are leading in deployments for testing and trials for virtualized wireless networks** (albeit they are doing this to varying degrees). Meanwhile, some geographies such as Europe and China appear to be less advanced. That said, we note Three UK is pursuing a virtualised approach to wireless, but this appears to have a greater emphasis on virtualising the core (and non real time functions).

**Exhibit 31: Key takeaways related to Rakuten's network from Dish Network's 2019 earnings**

Key takeaways from Dish Network 2019 earnings	
Capex savings	Dish stated it is confident that capex savings from virtualisation of wireless networks could be >25%.
The company also commented that operating expenses to run the network could be reduced if the operators virtualise the datacenter.	
Further softwarisation	Opex savings
Dish expects to follow a more extensive technological approach in its utilisation of wireless virtualisation/softwarisation vs Rakuten.	

Source: Company data

- We note that there is a burgeoning vendor ecosystem. Key players currently comprise Nokia, Ericsson, NEC, Cisco, Mavenir and AltioStar amongst others.

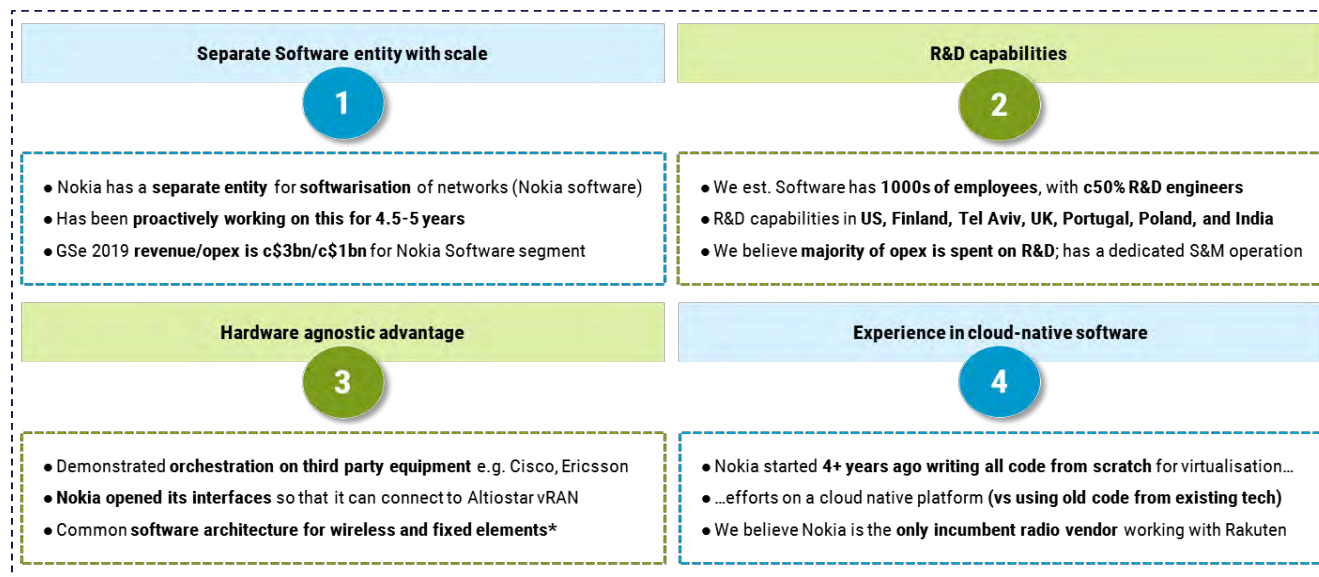
**Exhibit 32: Vendor ecosystem**

Overview of players with leading domains in softwarisation

		Nokia	Ericsson	NEC	AltioStar	Cisco	ZTE	Fujitsu	Mavenir	Ciena	Intel
1	Radio	Radio at cell site	✓	✓	✓			✓	✓		
2	Antenna	Antenna at cell site	✓	✓	✓			✓			
3	vRAN	Virtualised RAN software	✓	✓		✓			✓		
4	Optical	Physical optical connections	✓			✓		✓		✓	
5	Core/virtualised EPC	Virtualised core of network	✓	✓	✓	✓			✓		
6	BSS/OSS/Orchestration	Billing and operating functions	✓	✓	✓						
7	Systems integration	Software-defined networking	✓	✓		✓					
8	Datacenter processing	Base band processing chip									✓
9	Switching and routing	Network connectors	✓			✓	✓				

Source: Company data, Goldman Sachs Global Investment Research

- We believe **Nokia, so far, has been the most proactive amongst various equipment vendors in addressing the softwarisation trend given its participation in the Rakuten network.**

**Exhibit 33: Key factors supporting Nokia's participation in Rakuten's network**

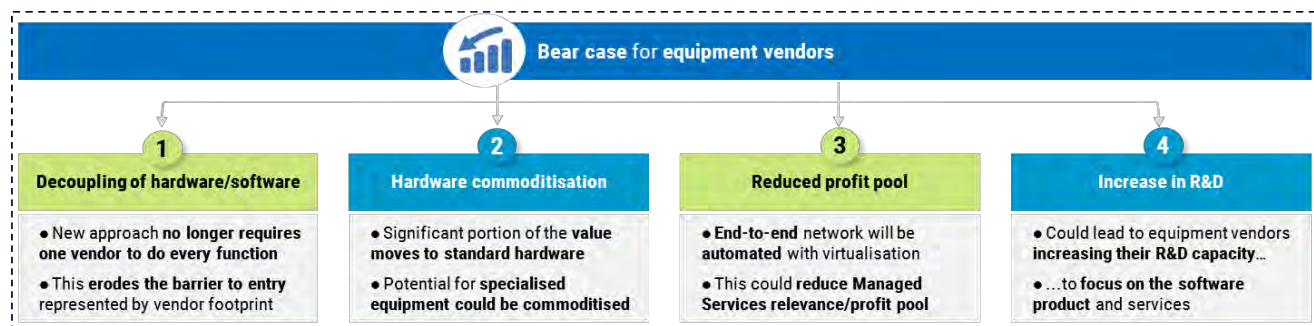
S&amp;M: Sales and Marketing \* e.g. mobile network, fiber, backhaul, routing, switching, optics, datacenter, Fixed access to home, etc.

Source: Company data, Goldman Sachs Global Investment Research

## Implications for equipment vendors: Potential risks and opportunities

- **We believe the shift from selling (and servicing) specialised wireless equipment hardware to providing software that runs on more standardised boxes (provided by other OEMs in the datacentre) could pose significant challenges to key existing wireless equipment vendors** if they fail to position themselves appropriately, but also potential opportunities.

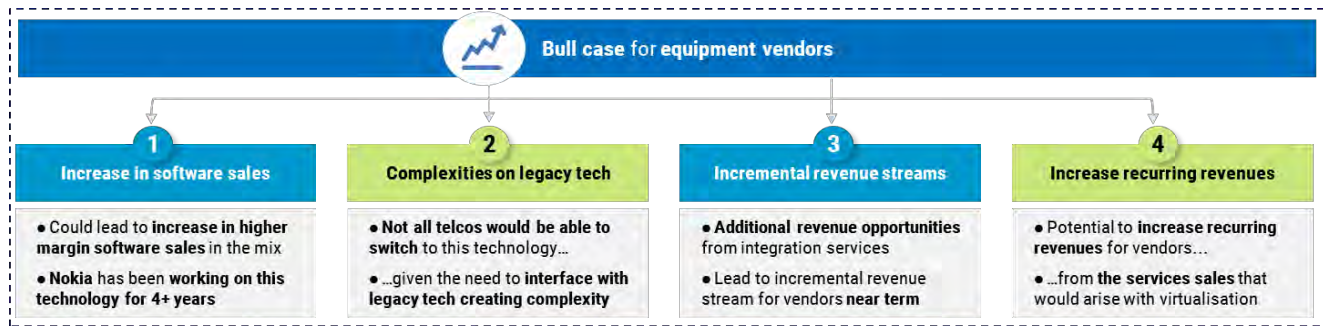
**Exhibit 34: Virtualisation could lead to commoditisation of specialised hardware and reduce Managed Services relevance**  
Bear case for equipment vendors



Source: Company data, Goldman Sachs Global Investment Research

- **We believe the real-time functions (i.e. DU) would need to be run on a FPGA SoC or a GPU within the edge cloud server.** This would still be more standardized/centralized than a traditional network, where processing occurs on specialised hardware on each base station.
- **Whereas base stations under the old model could be sold for tens of thousands of US\$, to the extent that real time functionality migrates to the edge cloud server/datacentre, this by definition reduces the hardware value that accrues to equipment vendors.** As such, it would be hard to justify such a high price if part of the processing is happening on non-specialised hardware (this is not provided by the equipment vendor).
- **Moreover, it creates risks of commoditisation, given that the new approach effectively decouples the provision of software functionality from hardware provision.** In other words, software from one vendor (not necessarily even a traditional wireless base station vendor) can run on totally different hardware from someone else.
- **We believe decoupling of the provisions for software and hardware by different vendors could be one of the biggest challenges for existing vendors, and could provide opportunities for the smaller vendors like NEC.** We argue this dynamic a) lowers barriers to entry for networking technology, b) reduces the competitive moat represented by the hardware installed base (and could allow new smaller vendors to take share), and c) could make it harder for equipment vendors to continue to charge high prices for equipment solutions (unless they can demonstrate they have market leading software).

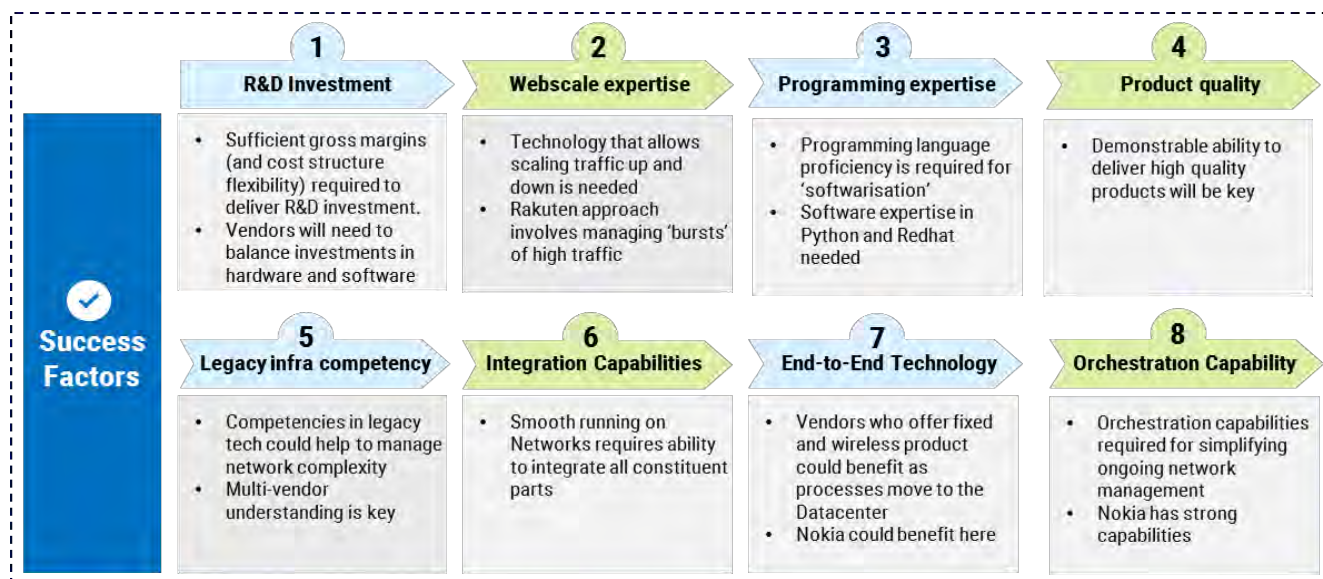
**Exhibit 35: In our view, virtualisation could potentially lead to a higher proportion of high margin software sales for equipment vendors**  
Bull case for equipment vendors



Source: Company data, Goldman Sachs Global Investment Research

- **Fundamentally a significant portion of current hardware sales - from an equipment vendor perspective - may well need to be compensated for by providing software for virtualising and integrating key network functions and orchestrating various operations.** Thus success in transitioning to provide such software is key for existing vendors. We believe this puts an emphasis on effective R&D spending, for example, while, on the upside, providing scope for higher profitability (given software is more margin rich than hardware). We believe the transition will not only involve incremental R&D spend, but a change in skillsets e.g. programming language expertise, which could require a change of approach (and potentially drive acquisitive M&A of software companies).

**Exhibit 36: We believe there are multiple success factors for equipment vendors to navigate the technology shift to virtualisation**



Source: Company data, Goldman Sachs Global Investment Research

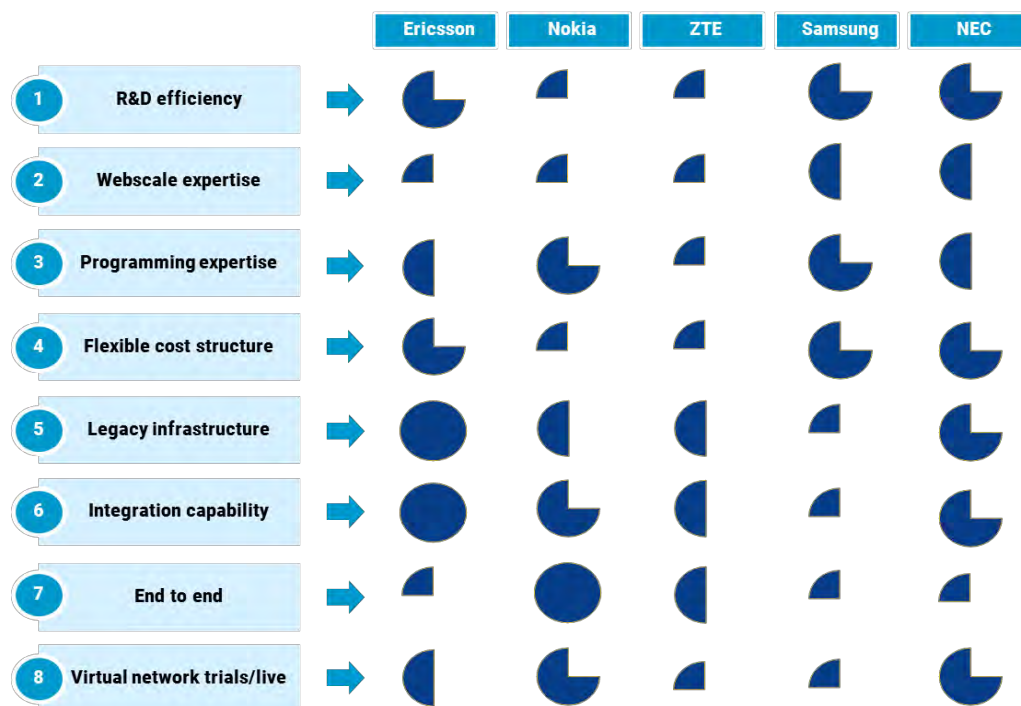
- **We note also that people heavy services (e.g. Managed Services where a vendor runs the telco's network) represent a high degree of sales (e.g. 12%/25% at Ericsson/Nokia in 2018) and could be under threat given the greater degree of automation of the network by machines (thus obviating the need for such a high degree of labour intensive work in running the networks.**



That said, this will to some extent be balanced by the shift to virtualisation involving incremental integration services opportunities.

- **Thus, we lay out a timeline for investors as well as key factors to monitor in weighing up vendors' scope to improve profitability** (by monetising software) and compensate for risks from hardware commoditisation.

**Exhibit 37: Snapshot of current capabilities relevant to softwarisation**



For example, we measure "End-to-end" based on broadness of the product portfolio, "Virtual networks trials/live" on the number of agreements a vendor is engaged in, "R&D efficiency" on investment capability, etc.

Source: Company data, Goldman Sachs Global Investment Research

- We reiterate our Sell on **Nokia**; while noting their proactive approach in this area we nevertheless see **11%/18% incremental upside/downside to our 12m PT** in our most positive/negative scenario. While we remain Buy rated on **Ericsson** (on CL) in the context of near term 5G driven cyclical demand improvement, **our analysis implies 4%/19% incremental upside/downside respectively**. We also analyse implications for Buy rated **NEC** (on CL), Buy rated **Cisco** and **ZTE** and for Buy rated **Rakuten** (see our Japanese team's recent Rakuten upgrade note [here](#)).

**Our scenario analysis suggests Nokia/Ericsson could see 18%/19% incremental downside (vs our current 12m PT) in a downside scenario, whereas we see 11%/4% incremental upside in a positive case**

We present scenario analyses for both Nokia and Ericsson to illustrate potential upside and downside cases with respect to impacts from Softwarisation.

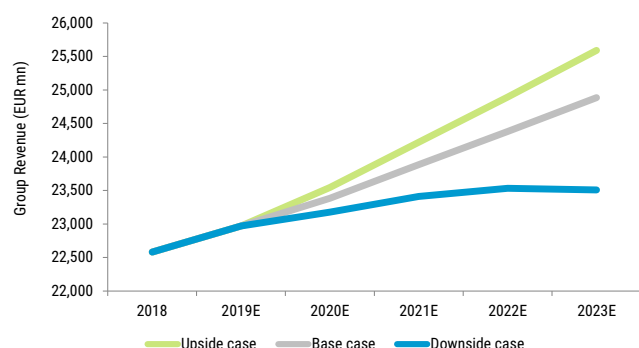
- In particular, we incorporate scenarios related to Wireless product, Network Rollout and Managed Services revenues, all of which could drive incremental downside for existing Wireless equipment vendors, whereas we also factor in potential upside from stronger Software sales.



- We believe both Nokia and Ericsson could see 18%/19% incremental downside (vs our current 12m PT) in a downside scenario, whereas we see 11%/4% incremental upside for NOK/ERIC in an upside case. We believe Nokia could potentially see higher incremental upside in a positive case primarily driven by its investments in its pure Software strategy.
- Our scenarios also imply 10%-20% incremental downside on 2021-23 EBIT estimates for Nokia, and 4%-8% incremental upside in an upside case.
- For Ericsson, we see an 10%-26% incremental downside on 2021-23 EBIT estimates, and 4%-7% incremental upside in an upside case.

**Exhibit 38: We see +3%/-6% impact on 2023E group revenue for Nokia in our most positive/negative scenario...**

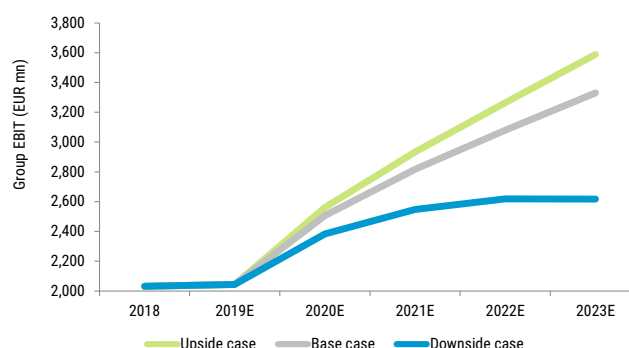
Nokia Group revenue scenario analysis (2018-23E)



Source: Goldman Sachs Global Investment Research

**Exhibit 39: ...with +8%/-21% impact on the 2023E group EBIT in our most positive/negative scenario**

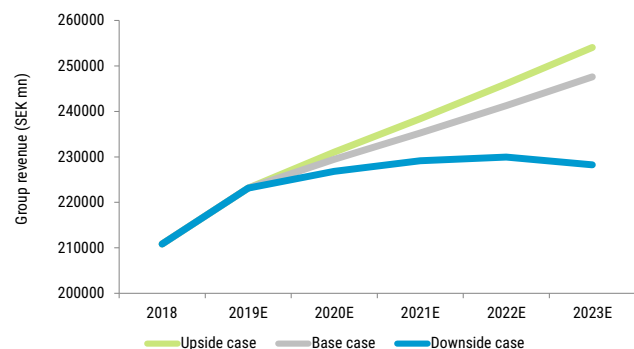
Nokia Group EBIT scenario analysis (2018-23E)



Source: Goldman Sachs Global Investment Research

**Exhibit 40: We see +3%/-8% impact on Ericsson's 2023E group revenue in our most positive/negative scenario...**

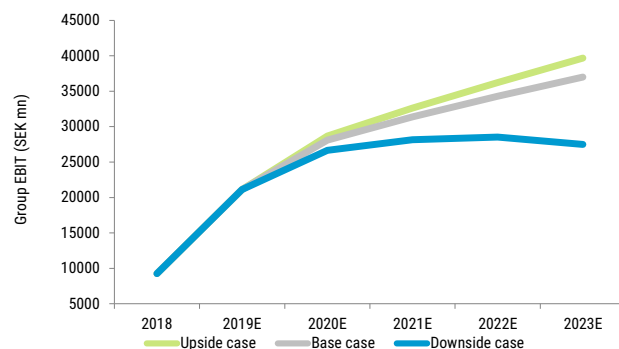
Ericsson Group revenue scenario analysis (2018-23E)



Source: Goldman Sachs Global Investment Research

**Exhibit 41: ...with +7%/-26% impact on 2023E group EBIT in our most positive/negative scenario**

Ericsson Group EBIT scenario analysis (2018-23E)



Source: Goldman Sachs Global Investment Research

**Key assumptions:**

**Wireless product revenues:** We believe there is scope for softwarisation to negatively impact the wireless hardware product (i.e. base stations) revenues for equipment vendors. As such, elements of the RAN being virtualised could reduce the value of products wireless equipment vendors sell (as functionality shifts to the cloud).

**Exhibit 42: Assumptions for estimating impact on wireless product revenues for Nokia and Ericsson**

	Downside case	Base case	Upside case
Existing global capex impacted	30.0%	10.0%	0.0%
Existing footprint virtualised	50.0%	25.0%	0.0%
Impact to wireless product sales	-50.0%	-40.0%	0.0%

Given we see up to 12 telcos globally which could shift towards virtualised RAN in coming years, we estimate (based on our bottom up capex model) this could account for c30% of global capex which could potentially be impacted in a downside case.

That said, of this we assume only a portion of the existing footprint of these telcos will be virtualised. As such, in a bear case we assume 15% of global capex is virtualised.

Source: Goldman Sachs Global Investment Research

**Network Rollout & Managed Services revenues:** We incorporate scenarios for negative impacts related to lower scope for network rollout services (given parts of the network are being virtualised and do not require hardware rollouts to the same extent). We also factor in impacts from lower managed services business for both Nokia and Ericsson given the increased level of automation in these cloud native networks (which require order of magnitude reductions in the number of people required to run the network).

**Exhibit 43: Assumptions for estimating impact on Network Rollout and Managed Services revenues for Nokia and Ericsson**

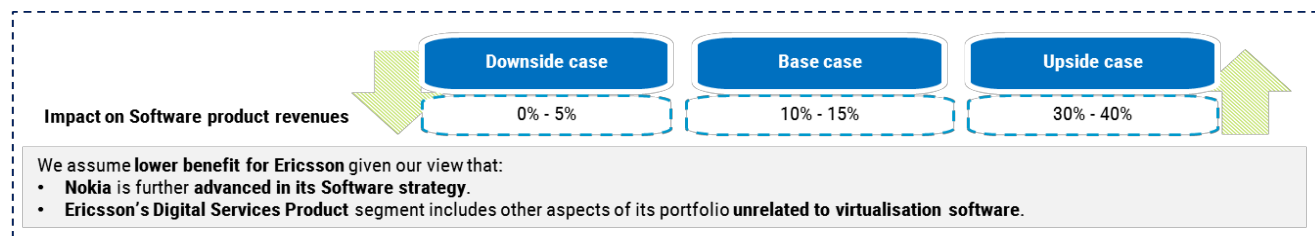
	Downside case	Base case	Upside case
Impact on Network Rollout revenues	-15.0%	-2.5%	0.0%
Impact on Managed Services revenues	-15.0%	-2.5%	0.0%

- Note the impact is analogous to the portion of the network which will be virtualised in each case
- Portion of network virtualised is equal to existing global capex impacted x existing footprint virtualised

Source: Goldman Sachs Global Investment Research

**Software product revenues:** We believe there is scope for upside skews to come from increased software product sales related to automation software – which is an incremental requirement with virtualised core and RAN networks.

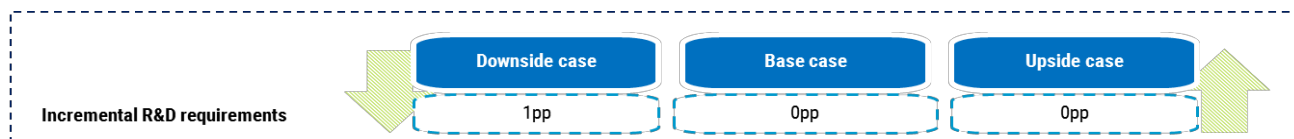
**Exhibit 44: Assumptions for estimating impact on Software product revenues for Nokia and Ericsson**



Source: Goldman Sachs Global Investment Research

**Incremental R&D requirements:** We believe given the increased level of automation software required in such networks, there is scope for increased R&D requirements for both NOK and ERIC.

**Exhibit 45: Assumptions for incremental R&D requirements**



Source: Goldman Sachs Global Investment Research

**We also include scenarios for both NOK and ERIC**, implying 18% and c19% incremental downside (vs current 12m PT) for NOK and ERIC in a downside scenario, whereas we see 4%/11% incremental upside for ERIC/NOK in an upside case. We believe Nokia could potentially see higher incremental upside in a positive case primarily driven by its investments in its pure Software strategy.

- We assume in a downside/upside scenario that Nokia could see a 6.0x/8.0x 2020E EV/EBITDA multiple ex-restructuring vs our published base case target multiple of 7.0x.
- For Ericsson, we assume in a downside/upside scenario it could see a 9.5x/10.5x 2020E EV/EBITDA multiple incl.-restructuring vs our published base case target multiple of 10.5x.

## **Implications for telecommunications infrastructure: Potential risks and opportunities**

### **Virtualization unlikely to impact US tower leasing activity in the near-to medium term**

- Virtualization has the potential to reduce the amount of networking equipment on (and beneath) towers as the centralized and distributed units get relocated off of macro sites and into data centers.
- While this trend could potentially reduce the space and load wireless carriers need to lease on towers, we do not see virtualization impacting tower leasing revenues over the near- to medium-term.
- This is for three reasons: 1) major US wireless carriers (VZ, T, TMUS and S) are locked into multi-year tower leases at rates predicated on traditional network architectures, 2) we expect major US wireless carriers to use traditional radio equipment in their networks for many years into the future and 3) potential incremental tower demand from DISH over the next several years – given the company's recent commitments to the FCC to deploy 15,000 cell sites and provide 5G coverage to 70% of the US population – should outweigh any industry level headwinds from network virtualization.

### **Potential long-term monetization for US towers**

- We believe network virtualization could actually be a tailwind to tower leasing activity over the long-term.
- This is possible if the new technology is able to bend the capex and opex curve enough that wireless operators opt to increase network capacity through cell site densification, rather than through incremental spectrum purchases.
- Further, edge compute facilities used in virtualized architecture may be, in some cases, deployed at the base of tower, which could provide an additional source of property leasing revenue to US tower operators such as American Tower, Crown Castle and SBA Communications.

### **Positive implications for fiber companies**

- We believe that virtualization will require dense fiber in order to connect the processing at the data center to the cell tower (called 'front haul' fiber).
- We believe the companies best positioned to benefit from this new fiber demand would be leading independent fiber providers, such as Zayo, Crown Castle and Uniti Group, as well as regional cable companies.

### **Positive implications for data center companies**

- A fully virtualized network would result in certain network elements being relocated from a macro site to a data center, which could drive colocation activity for US data center operators such as Equinix, QTS and Switch.
- However, we note that if these network elements mostly end up in edge data centers, the benefits to these existing colocation providers could be minimal as they do not operate edge facilities.

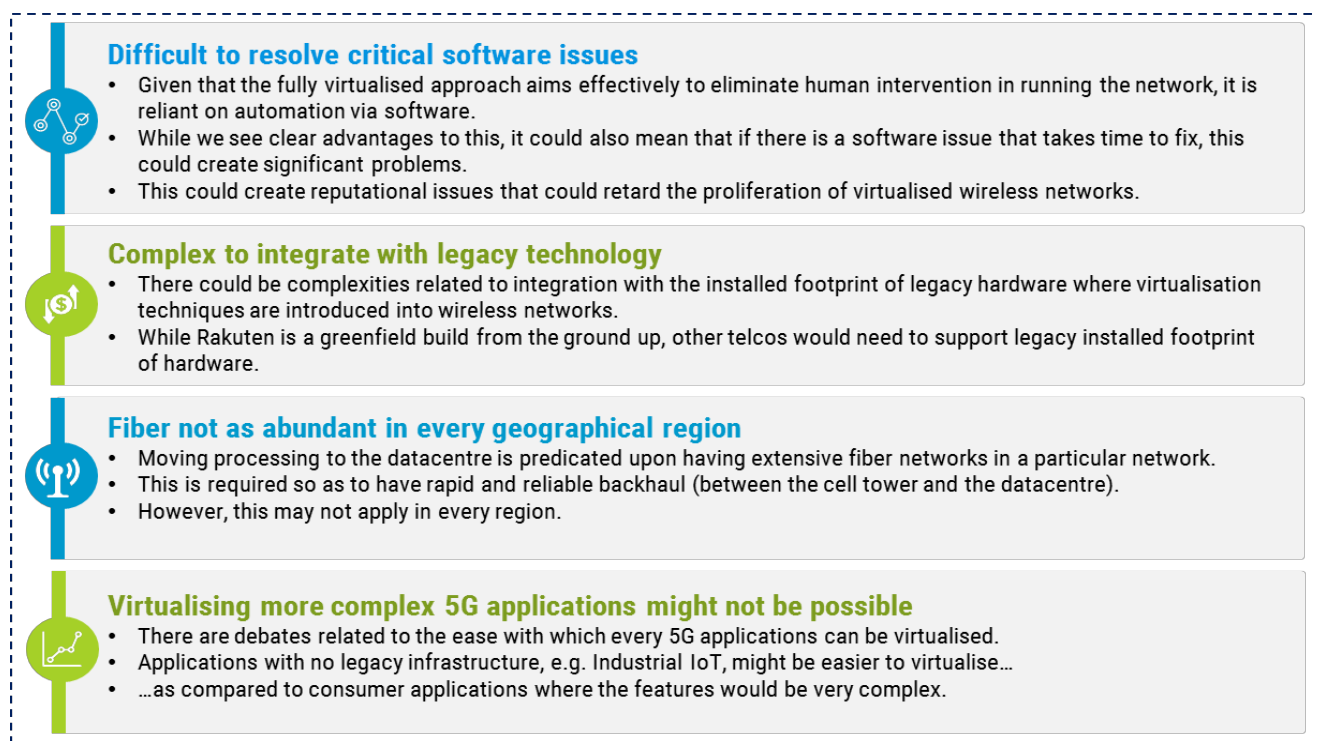
## The Cynic's View

There are various reasons why a shift to a virtualised approach could be less broad based on a global scale than we expect. Key risks to this trend include difficulties to resolve critical software issues, complexities when integrating with legacy technology, limited fiber in geographies, and difficulties in virtualising more complex 5G applications.

- Firstly, the software-based nature of a virtualised network could cause issues.
- Secondly, legacy integration poses difficulties as opposed to a greenfield build.
- Thirdly, lack of access to fiber could limit softwarisation scope. That said, we note efforts in the industry are underway to deliver technological solutions that will enable fronthaul for virtualisation more efficiently on fixed-connectivity other than fiber. Thus in regions where fiber is not as pervasive (and/or is costly), operators could deploy virtualised RAN. We note BT Labs, ADVA and Mavenir tested working on a similar solution in Feb 2018, and Altistar explicitly follows this approach.

### Exhibit 46: We believe there are several reasons why full softwarisation on a broad basis globally may not happen

Key risks



Source: Goldman Sachs Global Investment Research

- Fourth, some 5G applications may not have softwarisation potential. Furthermore, our industry discussions suggest some vendors believe (at least in the near term) that for some functions in the network, performance could be better on specialised hardware. However, we believe in the long term, progress could be made in this direction.



- Also, there have been debates around the performance of the network with multiple equipment vendors participating in the deployment.
- Traditional networks have different types of pre-installed equipment on the pre-existing cell sites vs no legacy hardware for the new ground up networks. Therefore, you can softwarise everything from the beginning in case of a greenfield network which can lead to cost savings. Thus, the benefits from softwarisation may not be as great for a traditional network shifting to softwarisation vs a greenfield network.
- Additionally, given the pre existing networks will already have built cell sites for 4G including site acquisition cost and backhaul cost, there will not be as much of a benefit from the lower site costs as would be seen on a greenfield network because the telcos would already have invested some costs in the pre-existing 4G site. Moreover, assuming 4G equipment has already being built out, this would remain on the cell site even if new 5G baseband equipment is to be centralized/virtualised. Thus, the related cost savings, e.g. site leasing, might be limited. Alternatively, one could switch out the pre-existing baseband but this could involve substantial costs. That said, in the long run, as the technology improves and the costs increase as function of Moore's law, we believe that introducing new virtualised technology will become more economical.
- Finally, Rakuten's fully virtualized wireless networks are yet to launch and hence are unproven. Furthermore, Rakuten's launch of its 4G network will initially be on a smaller scale geographically than originally envisaged, albeit we note this is largely due to company-specific factors e.g. labour shortages, rather than permanent technological showstoppers.

# Single stock implications

## Nokia (covered by Alexander Duval)

RATING	UPSIDE	PRICE	TARGET PRICE	MARKET CAP (US\$, mn)
SELL	-7.6%	€4.4	€4.1	27.7

### Company profile

Nokia's Networks business provides wireless and fixed-line networking solutions, including hardware, software and services for telcos, where it competes with Ericsson, Huawei and ZTE. Nokia's wireless business accounts for c.50% of its revenues.

### Implications

While we believe there are longer-term risks due to wireless virtualisation (50% of revenues could be potentially impacted), Nokia has been actively making progress in this space. For example, it is supplying hardware equipment and software to Rakuten, validating its near-term solid position in this domain. We believe Nokia is the most advanced traditional vendor in this space. Nokia is providing its cloud RAN, remote radio heads called AirScale, its cloud-native core technology named AirGile and several related software services to Rakuten. That said, we argue Ericsson could be better placed to invest longer term given higher gross margins, cost flexibility and FCF generation (on our estimates). We see 11%/18% incremental upside/downside to our 12m PT in our most positive/negative scenarios and 10%-20% impact on 2021-23E EBIT in a downside scenario and 4%-8% impact in an upside case.

### Investment thesis

We are Sell rated on Nokia as we continue to see short-term risks to software/hardware technical progress on 5G traditional base stations in the coming quarters. We note that NOK is trading at a 20% premium vs Ericsson on 2020E EV/EBITDA (ex-restructuring), despite the fact that ERIC's 2020E EBIT/gross margins ex-patents were 10.3%/35.9% vs NOK at 5.7%/35.1%. Our 12m SOTP-based price target is €4.1/ADR US\$4.6 with Networks valued at 8.0x 2020E EV/EBITDA pre-restructuring and a DCF for Technologies. Key risks include better-than-expected wireless capex, better-than-expected benefit from end-to-end offering and better cost-cutting.

### Exhibit 47: Company financials

GS Forecast	12/18	12/19E	12/20E	12/21E
Revenue (€ mn)	22,580.0	22,969.5	23,383.7	23,885.0
EBIT (€ mn)	2,032.0	2,043.7	2,505.6	2,816.7
EPS (€)	0.21	0.21	0.29	0.33
EV/sales (X)	1.1	1.1	1.1	1.0
EV/EBITDA (X)	9.3	9.1	8.2	7.5
P/E (X)	23.2	22.5	16.5	14.2
<b>Growth &amp; Margins (%)</b>	<b>12/18</b>	<b>12/19E</b>	<b>12/20E</b>	<b>12/21E</b>
Total revenue growth	(2.8)	1.7	1.8	2.1
EBITDA growth	(18.7)	5.4	12.0	10.3
EBIT growth	(21.4)	0.6	22.6	12.4
Op. margin (adj.)	9.0	8.9	10.7	11.8
EPS growth	(39.1)	2.0	36.3	16.1

Source: Company data, Goldman Sachs Global Investment Research

**Ericsson (covered by Alexander Duval)**

RATING	UPSIDE	PRICE	TARGET PRICE	MARKET CAP (US\$, mn)
CL-BUY	44.3%	Skr74.84	Skr108.00	25.8

**Company Profile**

Ericsson is a global telecom network infrastructure provider with headquarters in Sweden. The company offers hardware infrastructure (i.e., base stations), software and related services for wireless networks, where it competes with Nokia, Huawei, ZTE and Samsung. The company has pure wireless exposure and is not involved in fixed line.

**Implications**

While we are positive on Ericsson based on 5G cyclical demand improvement and self-help, we believe Ericsson will need, in the mid-term, to focus on key milestones related to network virtualisation given 90% of the revenues could be potentially affected. Ericsson has successfully virtualized the upper layer of 5G RAN software and has substantial engineering resources focused on RAN virtualisation. Ericsson signed a 5-year agreement with the software company VMware, aimed to help service providers deploy virtualized networks. It is working with 195+ customers for VNF transformation and has deployed its 5G cloud core for Telenor. Telecom Italia and Ericsson have also started to digitalize nationwide RAN. We think Ericsson's strategy will be to pursue both fully integrated hardware as well as a virtualised approach. However, ERIC is not a participating in the Rakuten network and we see Nokia as more proactive in full wireless virtualisation for now. That said, we note ERIC's solid recent R&D progress on traditional 5G hardware could augur well for longer-term virtualisation efforts. Our analysis implies 4%/17% incremental upside/downside to our 12m PT in our most positive/negative scenario, and a 10%-26% impact on 2021-23E EBIT in a downside scenario and a 4%-7% impact in an upside case.

**Investment Thesis**

We remain Buy (on CL) rated on Ericsson in the context of near-term 5G demand, share gains and self-help. Our 12-month price targets of SKr108/ADR\$11.5 are based on 10.5x 2020E EV/EBITDA post restructuring. We note Nokia trades at 20% premium to Ericsson on 2020E EV/EBITDA, despite our view that Ericsson is better positioned to benefit from 5G and potential upside skews from China vendor share shift. Key risks include worse cost control, a worse-than-expected wireless market and market share loss.

**Exhibit 48: Company Financials**

<b>GS Forecast</b>	<b>12/18</b>	<b>12/19E</b>	<b>12/20E</b>	<b>12/21E</b>
Revenue (Skr mn)	210,838.0	223,136.0	229,468.8	235,241.1
EBIT (Skr mn)	9,257.0	21,637.9	28,087.3	31,375.4
EPS (Skr)	(1.00)	3.27	5.33	6.44
EV/sales (X)	1.1	1.2	1.1	1.1
EV/EBITDA (X)	13.3	8.6	7.1	6.3
P/E (X)	NM	25.0	15.3	12.7
<b>Growth &amp; Margins (%)</b>	<b>12/18</b>	<b>12/19E</b>	<b>12/20E</b>	<b>12/21E</b>
Total revenue growth	4.7	5.8	2.8	2.5
EBITDA growth	(40.7)	83.4	15.7	7.7
EBIT growth	428.6	133.7	29.8	11.7
Op. margin (adj.)	4.4	9.5	12.2	13.3
EPS growth	83.3	426.7	63.1	20.7

Source: Company data, Goldman Sachs Global Investment Research

## ZTE (covered by Allen Chang)

RATING	UPSIDE	PRICE	TARGET PRICE	MARKET CAP (US\$, mn)
BUY	75.9%	HK\$19.90	HK\$35.00	10.6

### Company Profile

ZTE is a telecoms equipment maker and systems company based in China. The company operates in the carrier networks, consumer electronics (i.e., handsets) and enterprise communication sectors. ZTE provides wireless, optical transmission, data telecoms gear and telecoms software to its customers.

### Implications

We believe that 50% of the revenues could be potentially affected and that the company will need to navigate this transition. However, ZTE has announced certain activities related to virtualisation. For example, in May 2017 ZTE and Banglalink commercialised their virtual subscriber data management platform in Bangladesh, migrating 60 mn legacy users over to the new software. This created the world's largest virtual subscriber data management platform by capacity. This was done using generic hardware and successfully decoupled software from hardware components. ZTE looks to provide virtualised networks, and in 2016 deployed 40 globally. However, we note ZTE is not participating in the Rakuten network.

### Investment Thesis

We are constructive on ZTE given the structural growth of 5G upcycle and the company is a key telecom equipment vendor with 30% wireless market share in China ([more details about ZTE](#)). Our 12-month price target of HK\$35 for H-Shares is based on a 20x 2020E P/E and Rmb45 for A-Shares is based on a 30x 2020E P/E. Key risks to our Buy rating include: 1) A delay in China's 5G rollout, which would reduce 5G equipment demand in the near term; 2) US efforts to restrict ZTE products among its allies; and 3) Unexpected delay in ZTE's 5G technology, which could risk market share loss.

### Exhibit 49: Company Financials

GS Forecast	12/18	12/19E	12/20E	12/21E
Revenue (Rmb mn)	85,513.2	97,329.5	122,625.3	136,436.7
EBITDA (Rmb mn)	6,373.6	10,994.9	12,100.5	13,728.2
EPS (Rmb)	(1.67)	1.15	1.51	1.84
P/E (X)	NM	17.1	13.0	10.6
P/B (X)	3.0	3.0	2.4	2.0
Dividend yield (%)	0.0	0.0	0.0	0.0
N debt/EBITDA (ex lease,X)	0.5	0.1	(0.1)	(0.4)
Growth & Margins (%)	12/18	12/19E	12/20E	12/21E
Total revenue growth	(21.4)	13.8	26.0	11.3
EBITDA growth	(13.2)	72.5	10.1	13.5
EPS growth	(252.8)	168.8	31.3	22.1
DPS growth	NM	NM	NM	NM
EBIT margin	4.5	7.4	6.8	7.3
EBITDA margin	7.5	11.3	9.9	10.1
Net income margin	(8.2)	4.9	5.1	5.6

Source: Company data, Goldman Sachs Global Investment Research



## Fujitsu (covered by Ikuo Matsuhashi)

RATING	UPSIDE	PRICE	TARGET PRICE	MARKET CAP (US\$, mn)
NEUTRAL	-6.6%	¥8,190.00	¥7,650.00	15.7

### Company Profile

Fujitsu is a Japan-based company mainly engaged in providing IT solutions and communication technology solutions. It operates in four segments - System Platforms, Services, Ubiquitous Product and Devices. Within System Platforms, Fujitsu provides network products to telecom carriers including mobile infrastructure.

### Implications

We note Fujitsu announced a partnership with Ericsson in October 2018, which GS believes will help in reducing the R&D burden from the functional central-unit/distributed-unit (CU/DU) split in 5G RAN (when it is virtualised). With the partnership, Fujitsu can now focus its R&D on the DU side while leveraging the partnership for the CU side. For the core network, we expect Fujitsu to continue to re-sell other company's products. Currently Fujitsu is affected by limited investment by carriers.

### Investment Thesis

We are Neutral rated on Fujitsu with our 12-month price target of ¥7,650 based on a P/B of about 1.2X, derived from P/B-ROE correlation, and the midpoint of our FY3/20-FY3/21 estimates. Fujitsu's main customer is NTT DoCoMo (which is also a major customer for NEC), and we expect NTT DoCoMo's RAN/base station investments to increase as the carrier adopts new frequencies and launches 5G services. Risks include IT investment accelerating/decelerating faster than we expect, tolerance for upfront investment increasing again, and capital markets placing greater emphasis than expected on what we consider to be conservative FY3/20 guidance.

### Exhibit 50: Company financials

GS Forecast	2018	2019	2020E	2021E
Revenue (¥ bn)	4,098.4	3,952.4	3,839.0	3,874.0
Op. profit (¥ bn)	182.5	130.2	157.0	188.0
Op. profit CoE (¥ bn)	--	--	130.0	--
EPS (¥)	822.5	515.9	585.0	692.9
P/E (X)	9.5	14.0	14.3	12.1
P/B (X)	1.5	1.3	1.4	1.3
Dividend yield (%)	1.4	2.1	2.0	2.3
N debt/EBITDA (ex lease,X)	(0.3)	(0.7)	(0.3)	(0.7)
CROCI (%)	8.2	7.7	11.4	12.2
<b>Growth &amp; Margins (%)</b>	<b>2018</b>	<b>2019</b>	<b>2020E</b>	<b>2021E</b>
Total revenue growth	(9.1)	(3.6)	(2.9)	0.9
EBITDA growth	35.5	(27.1)	22.2	17.5
EPS growth	90.6	(37.3)	13.4	18.4
DPS growth	22.2	36.4	13.3	11.8
EBIT margin	4.5	3.3	4.1	4.9
EBITDA margin	4.8	3.7	4.6	5.4
Net income margin	3.9	2.6	3.1	3.6

Source: Company data, Goldman Sachs Global Investment Research

## Cisco Systems (covered by Rod Hall)

RATING	UPSIDE	PRICE	TARGET PRICE	MARKET CAP (US\$, mn)
BUY	19.5%	\$46.87	\$56.00	201.9

### Company Profile

Cisco is an American multinational technology firm, manufacturing networking technology serving both enterprise and telecommunications customers, as well as other IT infrastructure products such as servers, hyperconverged infrastructure, security, collaboration tools etc.

### Implications

Given that Cisco participates more on the fixed line (through its routers, optical systems, switches etc.) than RAN equipment/services side, we believe this trend could be an incremental opportunity. Cisco's technology in relation to Softwarisation is used by Rakuten. Cisco was chosen to supply 4000 edge nodes for Rakuten's wireless network to build network functions virtualization infrastructure. It is also providing switching and routing hardware, and related software. Being the primary systems integrator for Rakuten's telco cloud, virtualisation has the potential to be a driver of Cisco's performance.

### Investment Thesis

We are Buy rated on CSCO driven by Cisco's fundamentals looking out to the next 12-18 months as we expect the Catalyst 9K cycle to act as an idiosyncratic positive driver of earnings vs. the wider enterprise IT environment. Our 12-month price target of US\$56 is based on 17.0x our NTM non-GAAP EPS. Key downside risks include commoditization and margin compression, other headwinds to gross margins, competition and share losses, dilutive acquisitions and macroeconomic headwinds.

### Exhibit 51: Company Financials

GS Forecast	7/19	7/20E	7/21E	7/22E
Revenue (\$ mn)	51,904.0	53,015.3	55,192.4	56,695.1
EBITDA (\$ mn)	18,024.0	17,925.5	18,682.7	19,199.5
EBIT (\$ mn)	16,716.0	17,114.0	17,843.3	18,437.0
EPS (\$)	3.09	3.29	3.50	3.69
P/E (X)	16.1	14.2	13.4	12.7
EV/EBITDA (X)	11.7	10.5	9.7	9.1
FCF yield (%)	6.8	7.5	8.0	8.3
Dividend yield (%)	2.7	3.1	3.4	3.4
Net debt/EBITDA (X)	(0.5)	(0.5)	(0.7)	(0.9)
<b>Growth &amp; Margins (%)</b>	<b>7/19</b>	<b>7/20E</b>	<b>7/21E</b>	<b>7/22E</b>
Total revenue growth	5.2	2.1	4.1	2.7
EBITDA growth	9.7	(0.5)	4.2	2.8
EPS growth	18.8	6.4	6.4	5.5
DPS growth	9.7	7.4	8.2	0.0
Gross margin	64.5	64.9	64.9	64.9
EBIT margin	32.2	32.3	32.3	32.5

Source: Company data, Goldman Sachs Global Investment Research

## Rakuten (covered by Masaru Sugiyama)

RATING	UPSIDE	PRICE	TARGET PRICE	MARKET CAP (US\$, mn)
BUY	50.2%	¥932.00	¥1,400.00	11.4

### Company Profile

Rakuten Mobile Network (owned by Rakuten Inc., an internet services company), is the newest telco in Japan and has been building a wireless network from the ground up. Having chosen to partner with companies including Cisco, Nokia, AltioStar and NEC/Netcracker, Rakuten is leading the wireless virtualisation space.

### Implications

Rakuten will announce rate plans in early September and launch upgradable 4G services on October 1, with 5G networks to follow in 1H20. With technical network assessment steadily progressing, the company said that it has completed half the base station site contracts needed to achieve population coverage of 96%. We believe that the value of the telecom business will depend on subscriber numbers, acquisition cost, roaming costs, and the need for additional investments over the medium term rather than at the time of launch. In our view, if the network ultimately offers a positive user experience, and potentially benefits from some cost advantages vs. other telcos (albeit this should not be overstated), this could represent an upside skew (e.g., if Rakuten manages to acquire a single-digit percentage of Japan subscriber market share). In addition, we believe its strong eCommerce and credit card online bank portfolios could also be synergistic and represent upside skews in a bull case.

### Investment Thesis

We are Buy rated on Rakuten with a 12-month target price of ¥1,400; while our call is mainly based on valuation, we argue that, given the c.US\$5 bn-\$6 bn of capex Rakuten is investing, there is a reasonable chance its greenfield network can cover the vast majority of Japan. We believe the shares are pricing in a worst-case scenario regarding efficacy of the network, while we acknowledge the network has yet to launch (and the initial network scale will be more limited than originally envisaged). That said, given the significant investment and innovative technology approach, we believe the company could be successful in this venture. Key risks include Rakuten having a more efficient-than-expected method for customer acquisition, and additional investments in the telecom business causing sharp fluctuations in its value.

### Exhibit 52: Company Financials

GS Forecast	12/18	12/19E	12/20E	12/21E
Revenue (¥ bn)	1,101.5	1,148.7	1,292.2	1,394.0
Op. profit (¥ bn)	170.4	140.2	84.0	118.7
EPS (¥)	105.4	63.6	36.8	54.3
P/E (X)	8.0	14.7	25.3	17.2
P/B (X)	1.5	1.4	1.4	1.4
Dividend yield (%)	0.5%	0.6%	0.7%	0.8%
N debt/EBITDA (ex lease,X)	1.0	1.2	1.5	1.2
<b>Growth &amp; Margins (%)</b>	<b>12/18</b>	<b>12/19E</b>	<b>12/20E</b>	<b>12/21E</b>
Total revenue growth	16.6	4.3	12.5	7.9
EBITDA growth	19.2	(2.3)	(16.2)	26.3
EPS growth	31.7	(39.7)	(42.2)	47.8
DPS growth	0.0	33.3	8.3	7.7
EBIT margin	15.5	12.2	6.5	8.5
EBITDA margin	22.0	20.7	15.4	18.0
Net income margin	12.9	7.0	3.6	4.9

Source: Company data, Goldman Sachs Global Investment Research

## NEC (covered by Ikuo Matsuhashi)

RATING	UPSIDE	PRICE	TARGET PRICE	MARKET CAP (US\$, mn)
CL-BUY	15.2%	¥4,600.00	¥5,300.00	11.3

### Company Profile

NEC engages in providing information technology (IT) and network technologies globally, with its HQ in Japan. The company's products and services include systems integration, maintenance and support, outsourcing/cloud services and system equipment. It has five business divisions - Public, Enterprise, Network Services, System Platform and Global. Network Services supplies equipment to telcos for network implementation, network control platforms and operating services.

### Implications

NEC stands to benefit from virtualisation, as decoupling of software and hardware provisions could present additional opportunities for vendors like NEC. We note NEC is also cooperating with Rakuten to develop a 3.7 GHz massive MIMO 5G Antenna radio unit at its headquarters in Japan. Together they have developed a low power equipment which reduces operation and installation costs. Besides, NEC is offering a traditional end-to-end Billing Support System (BSS) and its wholly owned subsidiary Netcracker is supplying an Operating Support System (OSS) to support Rakuten's mobile network operator launch and subsequent operations.

### Investment Thesis

We remain positive on NEC given the scope to increase its sales in the security business and in the OSS/BSS businesses, which is mainly a part of Netcracker. We are Buy (on CL) rated and have a 12-month target price of ¥5,300. Our target price is based on a P/B of 1.4X, and the midpoint of our FY3/20-FY3/21 BPS estimates. Risks include unprofitable projects, uncertainty around the performance of overseas subsidiaries acquired by NEC, and slow improvement in earnings from global business.

### Exhibit 53: Company Financials

GS Forecast	3/19	3/20E	3/21E	3/22E
Revenue (¥ bn)	2,913.4	3,075.0	3,125.0	3,195.0
Op. profit (¥ bn)	58.5	130.0	148.0	162.0
EPS (¥)	154.8	337.7	385.0	418.9
P/E (X)	21.0	14.0	12.3	11.3
P/B (X)	1.0	1.3	1.2	1.1
Dividend yield (%)	1.2	1.3	1.7	2.1
Growth & Margins (%)	3/19	3/20E	3/21E	3/22E
Total revenue growth	2.4	5.5	1.6	2.2
EBITDA growth	(1.5)	55.5	7.8	5.7
EPS growth	(12.4)	118.2	14.0	8.8
DPS growth	(33.3)	50.0	33.3	25.0
EBIT margin	2.0	4.2	4.7	5.1
EBITDA margin	5.4	8.0	8.4	8.7
Net income margin	1.4	2.9	3.2	3.4

Source: Company data, Goldman Sachs Global Investment Research



## Samsung (covered by Daiki Takayama)

RATING	UPSIDE	PRICE	TARGET PRICE	MARKET CAP (US\$, mn)
BUY	29.1%	₩44,150.00	₩57,000.00	247.7

### Company Profile

Samsung is based in Korea and operates through three segments - Consumer Electronics (CE), IT & Mobile Communications (IM), and Device Solutions (DS). The IM division is further divided into two business lines - Mobile Communications, which engages in manufacturing and selling smartphones and related electronic accessories; and the Networks business, which offers equipment for building 4G/5G networks. Samsung is particularly focused on products related to mmWave spectrum, which can be an advantage for Fixed Wireless Access (FWA).

### Implications

We expect <5% revenue to be potentially affected from the shift to virtualised wireless networks. Samsung and SK Telecom completed the world's first 5G next-generation core trial in June 2018, featuring virtual network functions based on 3GPP release 15 standards and network slicing. Using this technology enables networks to identify service types and process traffic accordingly. For example, this could be used to detect an autonomous driving signal and process it with an ultra-low latency priority, as opposed to subscriber management that would not require such a real-time focus.

### Investment Thesis

We maintain our Buy rating and SOTP-based 12m TP of ₩57,000. We believe Samsung has scope to achieve 10% wireless market share in coming years (vs. 5% today). While Networking is <5% of group revenues, this could be a fast-growing revenue stream. Key risks include a major deterioration in memory supply/demand and/or a sharp contraction in smartphone margins.

### Exhibit 54: Company Financials

GS Forecast	12/18	12/19E	12/20E	12/21E
Revenue (W bn)	243,771.4	228,410.0	239,280.8	254,327.8
EBITDA (W bn)	85,368.7	54,805.3	65,458.6	75,766.3
EPS (W)	6,462	3,128	4,127	4,992
P/E (X)	7.2	13.6	10.3	8.5
P/B (X)	1.3	1.1	1.1	1.0
Dividend yield (%)	3.0	3.3	4.2	4.7
N debt/EBITDA (ex lease,X)	(1.0)	(1.6)	(1.4)	(1.4)
<b>Growth &amp; Margins (%)</b>	<b>12/18</b>	<b>12/19E</b>	<b>12/20E</b>	<b>12/21E</b>
Total revenue growth	1.8	(6.3)	4.8	6.3
EBITDA growth	12.7	(35.8)	19.4	15.7
EPS growth	10.5	(51.6)	31.9	21.0
DPS growth	66.6	0.0	27.1	11.1
EBIT margin	24.2	11.7	14.9	17.2
EBITDA margin	35.0	24.0	27.4	29.8
Net income margin	18.0	9.3	11.7	13.3

Source: Company data, Goldman Sachs Global Investment Research

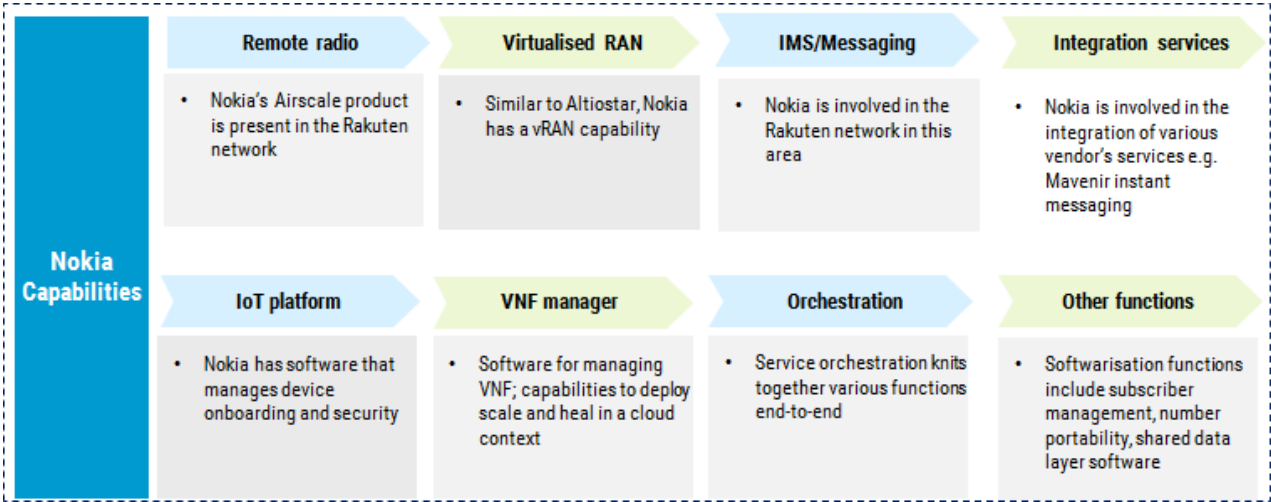
**Exhibit 55: Regional progress on virtualisation**

We see a varied picture among regions globally, with fully virtualised networks being launched first in Japan

<b>North America</b>	<ul style="list-style-type: none"> <li>In May 2019 Verizon announced <b>completed baseband virtualisation</b> trials in California, using Intel chips and <b>Nokia</b> base stations.</li> <li>Ericsson is working with Telecom Italia to softwareise RAN in Italy.</li> <li><b>Ericsson and Verizon</b> became the <b>first to introduce cloud-native technology</b> into a live wireless core in July 2019.</li> <li>AltioStar announced February 2018 that it is supplying <b>vRAN technology</b> to GCI's LTE network, <b>building foundations for 5G and IoT</b>.</li> <li>T-Mobile completed buildout of its <b>virtual EPC</b> using Cisco architecture across the U.S. in September 2018.</li> <li>AltioStar has secured \$357.5mn of private funding since 2011. CEO of Dish in the US stated on the company's 2Q19 results call that it expects to follow a technological approach which is <b>even more extensive in its utilisation of virtualisation/other techniques</b> than Rakuten.</li> <li><b>Most US telcos</b> are working on virtualising the core as well as the RAN.</li> </ul>
<b>Europe, Middle East &amp; Africa</b>	<ul style="list-style-type: none"> <li>In June 2018 Orange carried out <b>cloud RAN trials</b> using Nokia base stations in Poland, <b>70km away from the datacenter</b>.</li> <li>Ericsson <b>used VNF and deployed 5G cloud core solutions</b> for Telenor in Sweden, Norway and Denmark in November 2018.</li> <li><b>Telecom Italia</b> deployed Ericsson's vRAN technology into their live LTE network in August 2018.</li> <li>Telenor also signed a <b>strategic partnership with Cisco</b> exploring Open vRAN for 5G in March 2019.</li> <li><b>Three UK</b> went live with a <b>fully virtualised core</b> in July 2019.</li> </ul>
<b>Asia Pacific</b>	<ul style="list-style-type: none"> <li><b>Rakuten</b> to launch <b>fully virtualised end-to-end network in Japan from October 2019</b>.</li> <li>Mavenir is now bringing <b>end-to-end vRAN solutions</b> to operators, and showed live demonstrations at the India Mobile Congress in October 2018.</li> <li>In February 2017, AltioStar <b>trialed vRAN technology</b> for SK Telecom's network in Bundang, Korea.</li> <li>Nokia software has allowed Korea Telecom to conduct trials of <b>5G Network Function Virtualisation and network slicing</b> since February 2019.</li> <li>March 2015 in Japan, NTT <b>DoCoMo virtualised their network EPC</b> by sourcing from Ericsson and Cisco.</li> </ul>
<b>Latin America</b>	<ul style="list-style-type: none"> <li><b>NEC trialed</b> virtual customer premises equipment in <b>Brazil for VIVO</b> in June 2016.</li> <li>Cost savings could offer scope to accelerate 5G climate.</li> </ul>

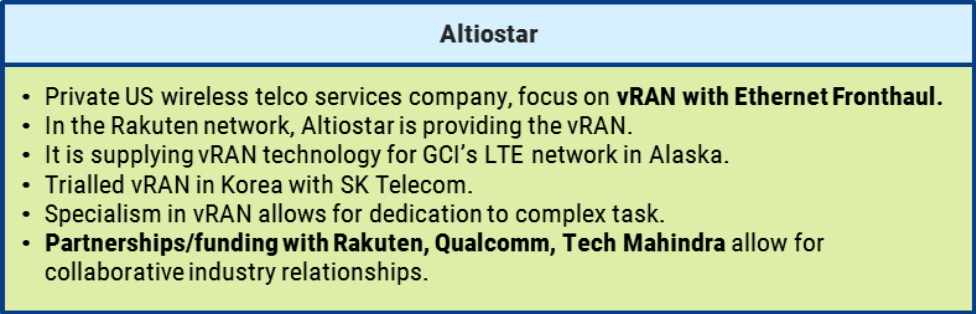
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 56: Key capabilities of Nokia



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 57: Profile of Altiostar



Source: Company data, Goldman Sachs Global Investment Research

# Disclosure Appendix

## Reg AC

We, Alexander Duval, Rod Hall, CFA, Ikuo Matsushashi, CMA, Masaru Sugiyama, Allen Chang, Daiki Takayama, Andrew Lee, Brett Feldman, Michael Bishop, Tina Hou, Giuni Lee, Bruce Lu, Hameed Awan, Aakriti Kakkar, Toshiya Hari, Mark Delaney, CFA, Ashwin Kesireddy, Lynn Luo, Jin Guo and Jeff Kim, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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Financial Returns and Multiple use the Goldman Sachs analyst forecasts at the fiscal year-end at least three quarters in the future. Growth uses inputs for the fiscal year at least seven quarters in the future compared with the year at least three quarters in the future (on a per-share basis for all metrics).

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Japan-Media: Dentsu, Hukuhodo DY Holdings.

Japan-Telecom & IT Services: Itochu Techno Solutions, KDDI, Nippon Telegraph & Telephone, Nomura Research Institute, NS Solutions, NTT Data, NTT DoCoMo, Otsuka, Softbank Corp., Softbank Group.

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## Target price history table(s)

### Samsung Electronics (Pref) (005935.KS)

Date of report	Target price (W)
21-Jul-19	44,000
17-Jun-19	40,000
02-Apr-19	41,000
31-Jan-19	40,000

### Samsung Electronics (005930.KS)

Date of report	Target price (W)
21-Jul-19	57,000
17-Jun-19	51,000
02-Apr-19	52,000
31-Jan-19	51,000



**Samsung Electronics (Pref) (005935.KS)**

Date of report	Target price (W)
08-Jan-19	36,500
11-Dec-18	39,500
31-Oct-18	43,300
12-Sep-18	44,100
06-Jul-18	52,400
26-Apr-18	2,660,000
02-Apr-18	2,580,000
08-Mar-18	2,550,000
31-Jan-18	2,660,000

**Samsung Electronics (005930.KS)**

Date of report	Target price (W)
08-Jan-19	48,000
11-Dec-18	52,000
31-Oct-18	57,000
12-Sep-18	58,000
06-Jul-18	69,000
26-Apr-18	3,500,000
02-Apr-18	3,400,000
08-Mar-18	3,350,000
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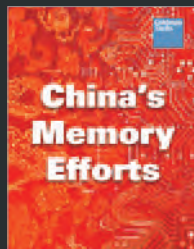
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