Seeing through the cloud

A survey of mobile operators' views on the evolution of the mobile core

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1. Introduction

Following up on last year's survey of mobile operators, which explored the sources of disruption in the wireless industry, we decided to narrow the focus this year to the mobile core – a part of the mobile network that is undergoing deep change and innovation. While the mobile core has traditionally been seen mostly as an unavoidable cost item needed to keep the network running, it is rapidly evolving into a powerful differentiator and a revenue engine.

This year's survey reports on how decision makers at mobile operators view the evolution in the mobile core. Survey participants were from advanced markets in APAC (26%), Europe (37%) and the Americas (37%), and mostly from tier-one mobile operators. As in the previous edition, the invitation-only survey focused on individual insights, to go past corporate strategy presentations, and take a closer look at how mobile operators manage the tradeoffs between cost-saving and revenue-generating efforts.

The paper summarizes the results of the survey in three sections. The first section presents a high-level view of the evolution in the mobile core and what the main sources of disruption will be. The second section focuses on the role of RCS in generating new revenues, fighting OTT providers' dominance, and improving subscriber experience. Finally, we move to the virtualization of the mobile core, and look at how mobile operators expect the cloud to help them lower costs and increase the efficient use of network resources.

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2. An expanded role for the new mobile core.

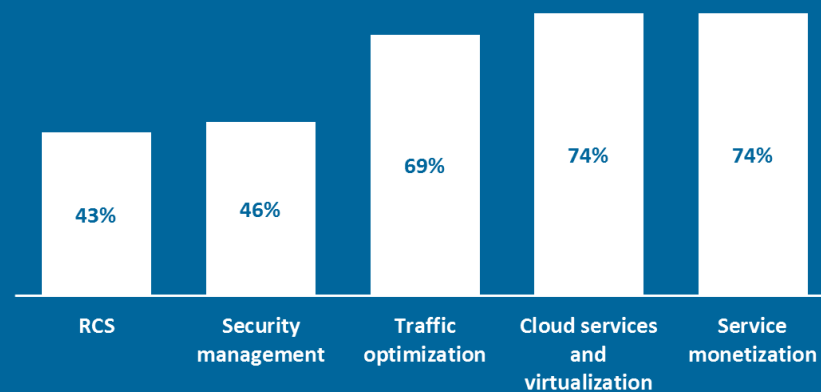## Traffic optimization and monetization today, but the future is in the cloud

The global view. The consensus among mobile network operators (here referred to as MNOs) is that the mobile core is rapidly evolving – and the changes are deep and have wide-ranging effects on end-to-end network performance and the services supported. Three factors are crucial in driving change:

- Adoption of the EPC, the new mobile core architecture in LTE.

- Growth in traffic volume and complexity , with more variety in traffic flows with different requirements.

- Pressure to monetize traffic growth to retain profitability and to invest in infrastructure upgrades.

> **"We are facing a huge amount of traffic growth that is accelerating with LTE. Our first priority is to monetize this traffic."**
> *European MNO*

The new LTE core has a prominent role in adding intelligence to the network, enabling new functionality, and supporting new services. It is rapidly becoming a part of the network that MNOs leverage for differentiation in markets where competition is increasing and more than high throughput rates is needed to attract new customers and retain existing ones.
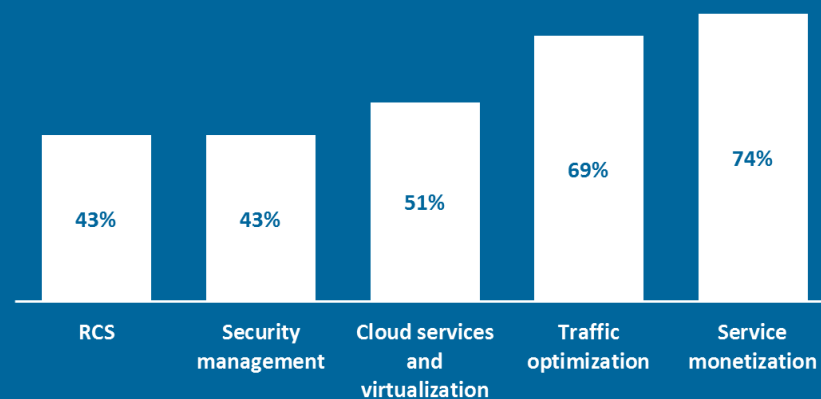
How disruptive will change in these areas be over the next five years?

RCS	Security management	Traffic optimization	Cloud services and virtualization	Service monetization
43%	46%	69%	74%	74%

Percentage of survey responses with a "high" rating.
Source: Senza Fili

What are the investment priorities today?

RCS	Security management	Cloud services and virtualization	Traffic optimization	Service monetization
43%	43%	51%	69%	74%

Percentage of survey responses with a "high" rating.
Source: Senza Fili

In this context, traffic optimization and service monetization are the first priorities in the short term. To a large extent they are complementary, because traffic optimization leverages tools such as DPI, QoS and policy to improve the utilization of network resources and to pave the way for service monetization. In last year's survey, many MNOs were skeptical that traffic optimization would work as promised or that it would lead to monetization.

Today, they see traffic optimization – rather than the creation of services that compete head-to-head with OTT players (in the rest of the paper we will refer to them as OTTs) – as the foundation of service monetization.

"Every MNO can do basic QoS and throttling, but moving beyond that requires a substantial increase in complexity in the core – for instance in the number of elements interacting with each other. It is scary, it really is scary. You can put sophisticated policy in place and have the RAN to support it, but if the core is not ready, you are in trouble."
American MNO

The urgency for service monetization and traffic optimization stems from a combination of increasing traffic load and eroding ARPU, and makes them the top targets for investment: traffic optimization is a high priority for 69% of respondents and service monetization is high for 74%. Both are expected to be main disruptors over the next five years.

Cloud and virtualization (74%) will have just as strong an impact as monetization, but it will take more time. MNOs believe that the opportunity exists, but moving to the cloud is risky. Some respondents feel that neither they nor their vendors are ready for it, but they are actively engaged in preparing for it, as evidenced by the recent creation of the ETSI NFV ISG, which includes many tier-one MNOs.

When do you expect to see traffic optimization?

Already happening — 43%
1 year — 27%
2–3 years — 27%
4+ years — 3%
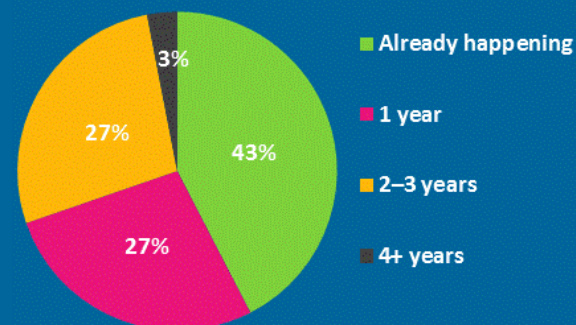
Percentage of survey responses. Source: Senza Fili

When do you expect to see service monetization?

Already happening — 47%
1 year — 25%
2–3 years — 25%
4+ years — 3%
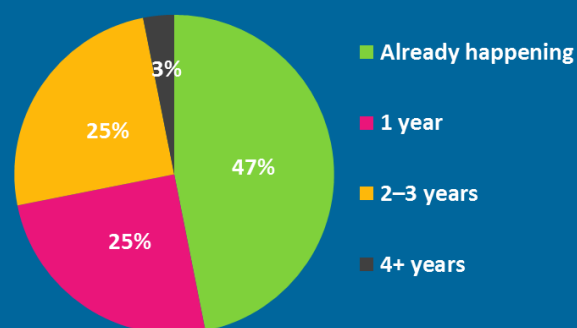
Percentage of survey responses. Source: Senza Fili

Regional perspectives. Responses on traffic optimization's disruptive power were consistent across regions (67% APAC, 69% Europe and the Americas), although APAC is more willing to invest in it (89%, versus 77% in Europe and 46% in the Americas). APAC is a stronger believer in the potential of the virtualized core (all APAC respondents rated it highly disruptive; 69% did in Europe and 62% in the Americas), but surprisingly it is less ready to invest in it than other regions (44% in APAC, 54% in Europe and the Americas). Europe is more sensitive to the impact from security (62%, versus APAC's 44% and the Americas' 31%).

RCS collects fewer high ratings in APAC (22%) than in Europe (46%) and the Americas (54%). Stronger support for RCS in the Americas is at least in part due to the fact that RCS – and VoLTE specifically – facilitates the MNOs' transition from CDMA to LTE. This also accounts for the greater importance placed on cost savings from RCS (discussed below) by American MNOs. Despite (or because of) a more contained decline in ARPU, American MNOs attach a higher disruptive potential to service monetization (85%, versus 69% in Europe and 67% in APAC).

"Our EPC core network is undergoing a fast transition as we move from basic access to VoLTE and RCS, and to more advanced policy. We are adding IMS components and improving integration with legacy networks. The higher number of elements inevitably increases the complexity in the core."

"Traditionally we have been a closed, walled community, but this is going to change. We have to get used to sharing more, and to provide the services that subscribers want at the price they are willing to pay."

American MNOs

3. RCS beyond monetization.
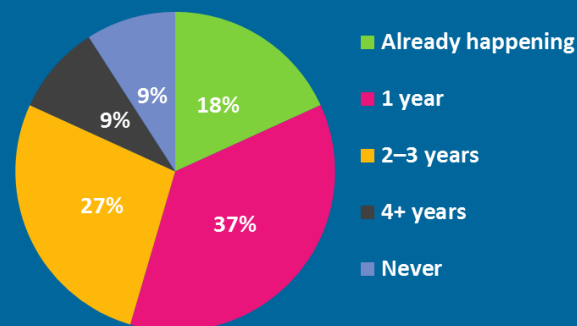## The winning weapon against OTT players?

The global view. Most MNOs are on a good trajectory on RCS and on VoLTE, the strongest driver behind RCS adoption. While 9% do not think that RCS will ever succeed, most have started to deploy such services (18%) or are getting ready to do so over the next year (37%).

> **"The revenue-generating potential of RCS goes beyond VoLTE. RCS enables MNOs to develop new services, and introduce presence, video communications, and high-fidelity voice. Monetization will be aided by the use of inter-user QoS and, hence, the ability to charge subscribers and services differently."**
> *American MNO*

RCS is seen as a differentiator and revenue-generating source, rather than a cost saver (26%) or a requirement (34%). MNOs view RCS as a key instrument to reverse the downward revenue trends in voice and SMS, which are still their main profit sources. RCS and, in particular, VoLTE are seen as improving and expanding voice services through the support of richer functionality, and as providing better integration with other services within the mobile device, across devices, and across operator-controlled and third-party applications.
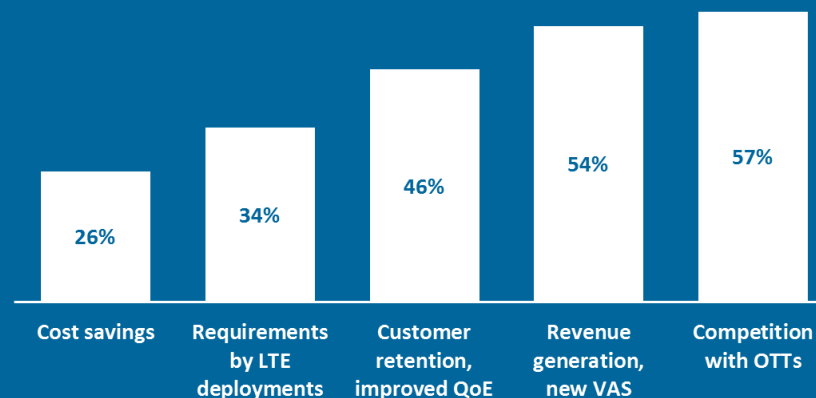
RCS will strengthen the competitive edge against other MNOs, but most respondents expect it to play an

When do you expect to see RCS rollouts?

- Already happening
- 1 year
- 2–3 years
- 4+ years
- Never

18% / 37% / 27% / 9% / 9%

Percentage of survey responses. Source: Senza Fili

RCS: What will accelerate adoption?

Cost savings	Requirements by LTE deployments	Customer retention, improved QoE	Revenue generation, new VAS	Competition with OTTs
26%	34%	46%	54%	57%

Percentage of survey responses with a "high" rating. Source: Senza Fili

important role in fighting OTTs (57%), supporting new services (54%), and, to a lesser extent, improving customer retention and QoE (46%).

The limited availability of mature solutions (63%) and the increase in complexity (54%) are among the top challenges MNOs see in deploying RCS. In considering the tradeoffs among different investment opportunities, many MNOs (57%) indicated that RCS rollouts may proceed at a slower pace than expected because the perceived benefits are limited, at a time when the expansion or deployment of LTE networks takes priority.
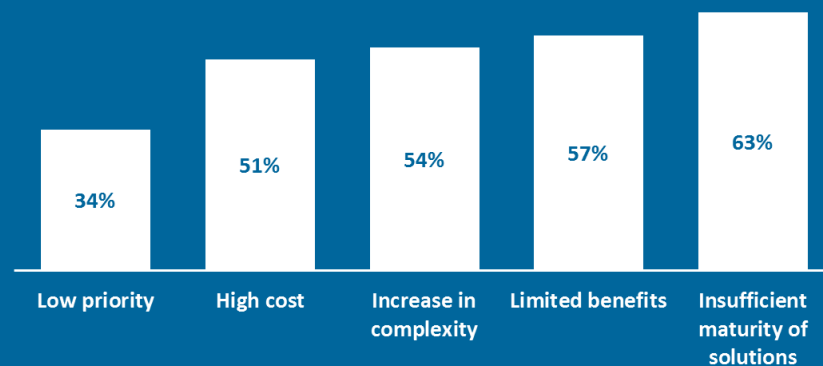
> "There is definitely a commitment to launch RCS and VoLTE, but it takes time to reach maturity – especially for services like VoLTE that rely on IMS as a fundamental enabler."
>
> "The MNOs can craft a better subscriber experience than the OTTs, and this gives MNOs a clear advantage. For instance, MNOs alone can support QoS-based access to applications."
> *American MNOs*

Competition with OTTs is a recurrent issue when talking about RCS. The ability to compete more effectively with OTTs by providing better performance, reliability and, ultimately, QoE is a major driver to deploy RCS. MNOs have long struggled against the appeal of OTT services such as Skype, YouTube or Pandora that are free to install and to use, and that subscribers started to use on their desktops or laptops before they even had a smartphone. More recently, services such as WhatsApp have challenged MNOs even more directly by offering, for free, services such as texting that are major profit sources for MNOs.
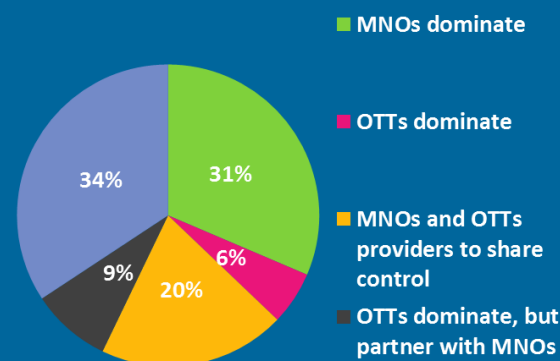
The question that is still open is whether MNOs will be able to capitalize on RCS and, specifically, on VoLTE, and regain the lost ground by

RCS: What may slow down deployment?

Low priority	High cost	Increase in complexity	Limited benefits	Insufficient maturity of solutions
34%	51%	54%	57%	63%

Percentage of survey responses with a "high" rating.
Source: Senza Fili

RCS: Who will control them?

- ■ MNOs dominate — 31%
- ■ OTTs dominate — 6%
- ■ MNOs and OTTs providers to share control — 20%
- ■ OTTs dominate, but partner with MNOs — 9%

34%

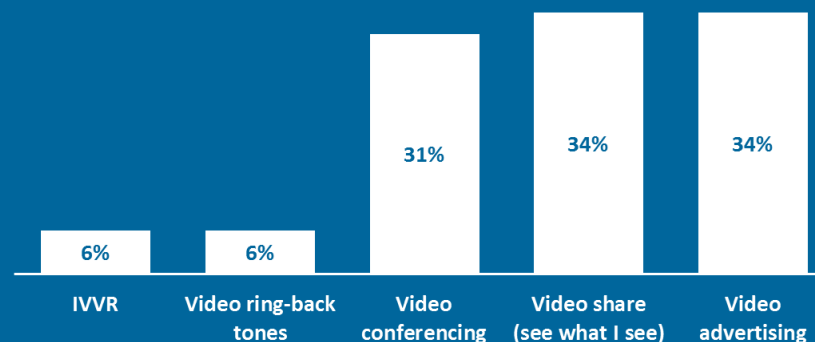*Percentage of survey responses. Source: Senza Fili*

leveraging the demand for RCS-type services – i.e., mostly voice, video communications, and messaging – that are better integrated with the devices and that perform better and more reliably, or whether their efforts are too little, too late to take subscribers away from OTTs. At the same time, RCS is expected to change the relationship with OTTs, possibly opening the way for partnerships or, conversely, for increased competition.

Perhaps not too surprisingly, only 6% of the MNOs participating in the survey expect OTTs to dominate in RCS. Overall, opinion varies significantly, with almost a third (31%) expecting MNOs to dominate the RCS market, while another third (34%) anticipates a continuing fight against OTTs. A third group of MNOs believes that there is room for coexistence between MNOs and OTTs: according to 20% of respondents, MNOs and OTTs will share control over RCS. An additional 9% of respondents believe that partnerships with OTTs are a more promising way forward. In the absence of an emerging consensus, we expect to see each MNO chart its own course – an approach that will provide a great learning opportunity for the entire industry.

Finally we asked survey respondents their view of video communications. MNOs agreed that IVVR and video ring-back tones will have a small impact (6% in both cases), while video sharing (34%), video advertising (34%) and video conferencing (31%) are more attractive to both consumer and enterprise subscribers, and may generate additional revenues or at least act as a service differentiator.

Regional perspectives. The rollout timeline is consistent across regions, but the regions differ in how they rate the impact of drivers that will either accelerate or slow down deployment. Revenue generation and the addition of VAS figures most prominently in the Americas, as does competition with OTTs (revenue generation and VAS: 69% in the Americas, versus 46% in Europe and 44% in APAC; competition with OTTs: 69%, versus 54% in Europe and 44% in APAC). The potential for cost savings from RCS is more important to American MNOs than to others (38%, versus 31% in Europe and 0% in APAC).
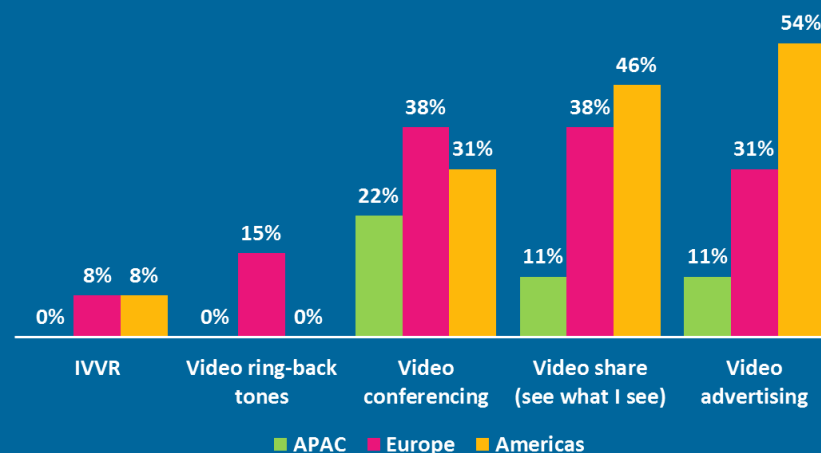

RCS: What is the impact of video services?

IVVR	Video ring-back tones	Video conferencing	Video share (see what I see)	Video advertising
6%	6%	31%	34%	34%

Percentage of survey responses with a "high" rating.
Source: Senza Fili

RCS: Impact of video services by geography

Percentage of survey responses with a "high" rating.
Source: Senza Fili

APAC ■ Europe ■ Americas

Among the factors that might slow down deployments, American MNOs are more worried about the increase in complexity (69%, versus 54% in Europe and 33% in APAC), while Europeans worry about the insufficient maturity of solutions (85%, versus 62% in the Americas and 33% in APAC) and the cost (69%, versus 44% in APAC and 38% in the Americas).

APAC MNOs are the staunchest believers that MNOs will dominate over OTTs (56%, versus 23% in Europe and in the Americas). Nearly half of European MNOs expect to continue to fight against OTTs (46%, versus 31% in the Americas and 22% in APAC), and almost a third of American MNOs believe that OTTs and MNOs will share control (31%, versus 15% in Europe and 11% in APAC).

Radisys MPX-12000 MRF. Source: Radisys

MNOs in the Americas are the most enthusiastic believers in video advertising, with 54% rating the impact of video advertising as high, compared to 31% in Europe and 11% in APAC. American MNOs are also more supportive of video-share services (46%, versus 38% in Europe and 11% in APAC), while Europeans see a big opportunity in video conferencing (38%, versus 31% in the Americas and 22% in APAC).

"RCS is not an option for MNOs. It is necessary to continue to provide services such as voice, SMS and MMS. Our current focus is to try to understand RCS usage models so we can learn to monetize them."
European MNO

"RCS will enable us to make the same services available across devices. When they get a new device, subscribers know that their favorite applications will still work. This puts MNOs in a better position to compete with OTTs, which already support applications across mobile and fixed devices."

"MNOs can develop partnerships with OTTs, granting them access to some of the QoS functionality through revenue-sharing agreements. Such partnerships may prove to be a win-win proposition for both MNOs and OTTs."

"Roaming is a crucial revenue generator for LTE, but there is still more work to be done before we can roll out VoLTE roaming."

"RCS is not a mature ecosystem at this point, especially on the device side. Among the vendors only a few have robust solutions. This is creating delays in the rollout of VoLTE."

"VoLTE will enable us to keep subscribers on LTE. And in turn, the more traffic we can move to LTE, the sooner we can transition beyond legacy networks."
American MNOs

4. Getting ready for a virtualized core.
What's in it for the operators?

> "Within the EPC so much is still unproven and untested, that we have to be careful as we move towards the cloud. We need to get our networks fully loaded to understand how different elements work together, what the requirements are, and what is the best way to share common network resources among them."
> *American MNO*

> "Work being done in the ETSI NFV group will allow MNOs to develop common requirements and articulate them to vendors."
> *Asian MNO*

The global view. The virtualization of the LTE core is where MNOs expect to see the most profound changes in the long term. Among survey participants, 71% anticipated that cloud and virtualization of the mobile core will be the hottest topic at the 2013 Mobile World Congress. A strong MNO participation in the NFV ETSI initiative confirmed the need, identified by survey participants, for MNOs to work together to jointly develop a solid foundation for SDN in mobile networks – both to avoid fragmentation and to maximize cost savings and efficiency.
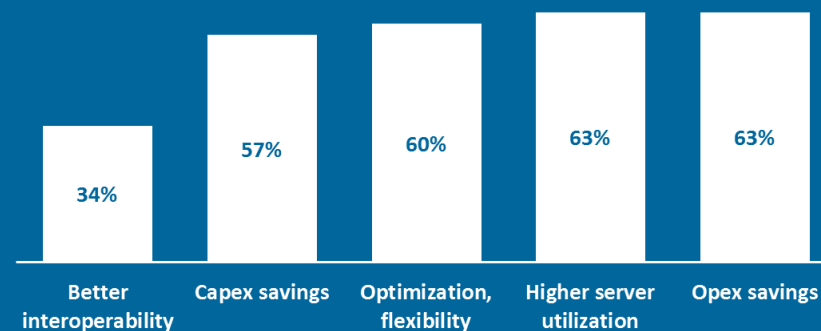
While its adoption is farther in the future than that of traffic management and service monetization, which are the top-of-mind issues for MNOs today, the cloud is expected to transform the way MNOs run their network and track its performance, and in the process take on a larger role in integrating the network and

When do you expect to see virtualization in the mobile core?
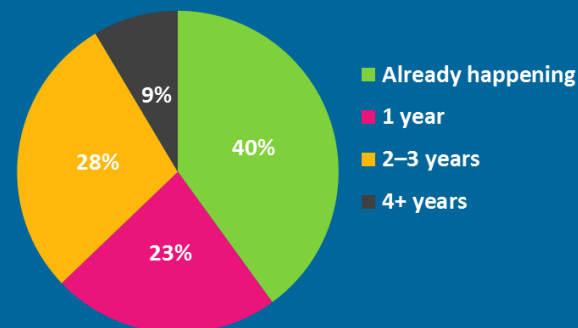
- Already happening
- 1 year
- 2–3 years
- 4+ years

40%
23%
28%
9%

Percentage of survey responses. Source: Senza Fili

Cloud services and virtualization: What are the benefits?

Better interoperability	Capex savings	Optimization, flexibility	Higher server utilization	Opex savings
34%	57%	60%	63%	63%

Percentage of survey responses with a "high" rating.
Source: Senza Fili

developing new relationships with equipment and solution vendors. Although many MNOs (40%) indicate that virtualization is already ongoing, they are proceeding with caution, moving one step at a time to maintain performance and reliability levels as they move some functions to the cloud.

MNOs agree on the benefits of a cloud environment. From a performance perspective, a virtualized core gives them the flexibility they need to use network resources more efficiently, at a time when traffic loads and characteristics are becoming less homogeneous and difficult to predict. Cost savings also figure prominently among the benefits, because the virtualization of core elements allows MNOs to purchase lower-cost equipment and have more flexibility in how they use it.

At the same time, the transition to the cloud is not easy. Among the concerns, security and privacy rank highest (74%), because virtualization forces MNOs to move past the familiar environment they are accustomed to. MNOs also worry that existing solutions lack maturity and are not as reliable as needed (60%). They complain that vendors are not as eager as they would like them to be in developing new and reliable solutions for a cloud environment. They suggest that vendors –

especially tier one vendors – are reluctant to accept the risks that virtualization inevitably brings. This may open a market opportunity for new or more focused vendors.

The sequence in which core functions are to be virtualized is crucial to the success of the overall process. The trend among MNOs is to start at the periphery and with new functions, and when they are satisfied with the performance, gradually move to more central functions, where the risk is

> **"Virtualization will enable MNOs to avoid vendor lock-in. The software will run on hardware from any vendor, and this will allow MNOs to choose the hardware vendors they want."**
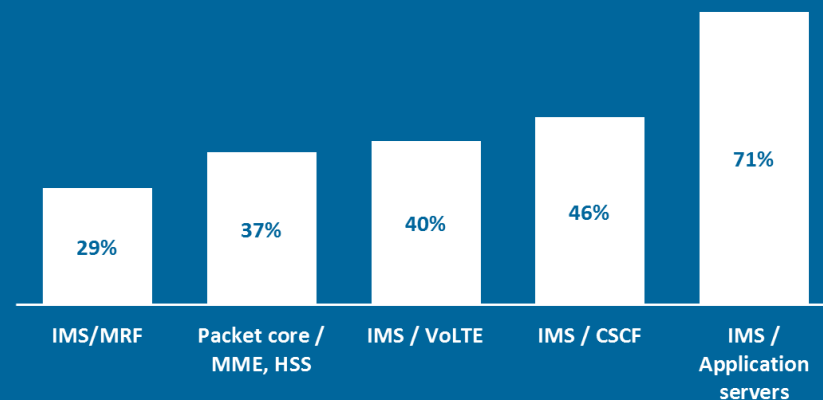> *European MNO*

Cloud services and virtualization: What are the risks?
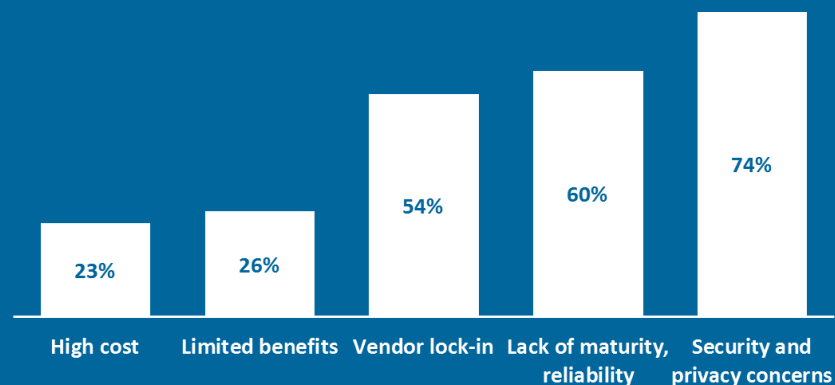
Percentage of survey responses with a "high" rating.
Source: Senza Fili

Cloud services and virtualization: Which applications/functions are better suited?

Percentage of survey responses with a "high" rating.
Source: Senza Fili

inherently higher. This approach explains why IMS application servers are treated as the function best suited to being virtualized (71%), and less support went to other IMS functions tied to voice and signaling (CSCF 46%, VoLTE 40%, MRF 29%) and packet core control-plane elements (MME and HSS, 37%). Some MNOs noted that the benefits of virtualization decrease as we move toward more fundamental core functions, because flexibility in the allocation of resources does not significantly reduce the equipment capacity needed. The tight latency and capacity requirements in the user plane eliminate most of the advantage of virtualization in the user plane.

"Virtualization is much more compelling for functions that are more peripheral, such as OCS and policy. This is where the virtualization will start because the risks are more contained.

As we move to EPC basic functionality – SGW, PGW – the role for virtualization is more limited. In high-traffic areas, dedicated equipment that allows for a high level of optimization will continue to dominate. In secondary markets or rural areas, virtualization may play a role as it provides flexibility in allocating network resources, and cost savings."
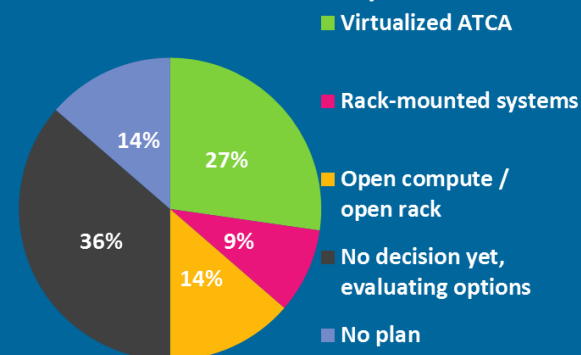*American MNO*

The choice of platform and the cloud type are the areas with the most uncertainty. Just over a third of survey participants (36%) still have to decide which type of cloud is best suited to their needs. Among MNOs that have settled on their cloud strategy, most prefer a hybrid cloud (34%) because it will enable them to reap the benefits of both the private (13%) and public (16%) cloud.

Cloud services and virtualization: Public, private or hybrid cloud?
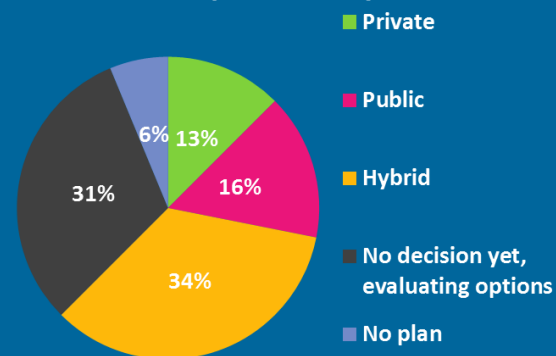
- Private
- Public
- Hybrid
- No decision yet, evaluating options
- No plan

6% 13% 16% 34% 31%

Percentage of survey responses. Source: Senza Fili

Cloud services and virtualization: What is the best platform?

- Virtualized ATCA
- Rack-mounted systems
- Open compute / open rack
- No decision yet, evaluating options
- No plan

14% 27% 9% 14% 36%

Percentage of survey responses. Source: Senza Fili

The ATCA platform was the preferred option. Among MNOs that have selected a platform, more than half (27% of all MNOs surveyed) have chosen an ATCA platform, and the rest have opted for rack-mounted systems (9%) or open compute / open rack platforms (14%). Half of the respondents (50%) have not yet selected a platform, but they are evaluating different options.

> "Virtualization will change the value chain – and specifically the role of MNOs within it. Software and hardware integration will no longer be the responsibility of the vendors. MNOs may decide to take a larger role in doing the integration in house, or hire a third party to do so."
> *European MNO*

Radisys ATCA T-series platform. Source: Radisys.

Regional perspectives. APAC MNOs are more aggressively moving to the cloud, with implementation under way for 78% of them, compared to 31% in Europe and 23% in the Americas. The perceived risks in moving to a cloud environment don't change much across regions, but APAC MNOs are the most concerned about the risk of vendor lock-in (78%, versus 54% in Europe and 38% in the Americas), while European MNOs have more reservations about lack of maturity and reliability of solutions (69%, versus 56% in APAC and 54% in the Americas).

The choice of best-suited functions is uniform across regions. Variation in platform choice was more marked. European (38%) and APAC (33%) MNOs supported ATCA platforms more strongly than MNOs in the Americas (13%). Among American MNOs, 63% have not made a decision yet, compared to 51% among European MNOs and only 34% among APAC MNOs.

5. Conclusions.
Leveraging the new mobile core to create value

The adoption of LTE and of the EPC, along with the pressure to accommodate higher traffic loads and create new revenue sources, has led MNOs to change their view of the mobile core and to expand its role and functionality. For a long time, the core was treated by many MNOs as crucial to ensuring performance and reliability of basic functions, but lacking the innovative pace of the RAN infrastructure. Even during last year's survey, most respondents were more interested in new devices and changes in the RAN than in the evolution of the core, with VoLTE as the only exception.

The balance is changing, with the mobile core attracting more attention as its role expands to optimize network performance and resource utilization, to enable new services and new charging models, and to secure data traffic. From a financial perspective, the mobile core's increased efficiency (e.g., traffic management) is conducive to lower network costs, while the new functionality (e.g., policy, QoS, DPI) enables new revenue sources. Through VoLTE, the LTE core fundamentally alters the way MNOs support voice services, not only by moving from packet-switched voice to VoIP, but also by integrating voice communications into the wider universe of data services, including video. Finally, the virtualization of the core provides a longer-term evolution toward an entirely new way to plan and use core-element resources, manage functions within the network, and work with vendors.

Traffic optimization and service monetization have been the first drivers in the evolution of the mobile core. Although most MNOs are still in the early adoption phase, this year's survey indicates that a lot of progress has been made. Not only have MNOs left behind some of their concerns about complexity, risk and reliability, they have also come to see traffic optimization as a necessity rather than an option, and service monetization as the highest-priority target.

Views on RCS are more varied. While MNOs are working on RCS deployments or are planning for them, there is a lower sense of urgency than for traffic optimization, service monetization, or virtualization of core functions. As a way to fight OTTs' dominance, improve QoE and customer retention, and enable new services, RCS is seen as a key tool that MNOs are on track to deploy, but whose value proposition is not fully proven. RCS may improve the subscriber experience, and yet fail to deliver new revenues or to gain ground over OTTs.

The virtualization of core functions emerges from the survey as the trend in the evolution of the mobile core that carries the largest opportunity, in terms of increasing the flexibility in the use of network resources and reducing costs. MNOs are still working on their strategy, and many are still evaluating the choices among cloud types and platforms, with hybrid cloud and ATCA showing an early advantage. But virtualization also presents the most challenging risks. Lack of mature solutions, reliability and security are among the main concerns that MNOs face, but most of the MNOs we talked to appear to be ready to address them by cautiously steering their path toward the cloud – being selective about the functions they virtualize along the way – to preserve network performance and reliability as they learn to operate in the new environment.

6. Methodology

Our survey was conducted in the period from December 2012 to February 2013. It included a limited number of decision makers (35) from MNOs in advanced markets in APAC (26%), Europe (37%) and the Americas (37%), who were individually invited to participate. Most participants (81%) were from tier-one MNOs. Survey participants answered an online survey and were afterwards interviewed to discuss their responses in more depth.

The goal of the survey was to provide an in-depth view of what key people who drive change at MNOs see as the disruptive changes in the mobile core over the next five years. To accomplish this, we asked participants to share with us their individual insights on the topics covered, rather than presenting the corporate views of the MNO.

7. Acronyms

3G	Third generation
3GPP	Third Generation Partnership Project
4G	Fourth generation
APAC	Asia Pacific
ARPU	Average revenue per user
ATCA	Advanced Telecommunications Computing Architecture
CDMA	Code Division Multiple Access

CSCF	Call Session Control Function
DPI	Deep packet inspection
EPC	Evolved packet core
ETSI	European Telecommunications Standards Institute
HSS	Home Subscriber Server
IMS	IP multimedia subsystem
IP	Internet protocol
ISG	Industry specification group
IVVR	Interactive video voice response
LTE	Long term evolution
MME	Mobility management entity
MNO	Mobile network operator
MRF	Media resource function
NFV	Network Functions Virtualization
OTT	Over-the-top, over-the-top player
QoE	Quality of experience
QoS	Quality of service
RAN	Radio access network
RCS	Rich communication service
SDN	Software-defined networking
SMS	Short message service
VAS	Value-added service
VoIP	Voice over IP
VoLTE	Voice over LTE

About Radisys

Radisys (NASDAQ: RSYS) is a market leader enabling wireless infrastructure solutions for telecom, aerospace and defense applications. Radisys' market-leading ATCA and MRF (Media Resource Function) platforms coupled with world-renowned Trillium software, services and market expertise enable customers to bring high-value products and services to market faster with lower investment and risk. Radisys solutions are used in a wide variety of 3G & 4G / LTE mobile network applications including: Radio Access Networks (RAN) solutions, wireless core network applications, Deep Packet Inspection (DPI) and policy management; conferencing and media services including voice, video and data.

About Senza Fili

Senza Fili provides advisory support on wireless data technologies and services. At Senza Fili we have in-depth expertise in financial modelling, market forecasts and research, white paper preparation, business plan support, RFP preparation and management, due diligence, and training. Our client base is international and spans the entire value chain: clients include wireline, fixed wireless, and mobile operators, enterprises and other vertical players, vendors, system integrators, investors, regulators, and industry associations.

We provide a bridge between technologies and services, helping our clients assess established and emerging technologies, leverage these technologies to support new or existing services, and build solid, profitable business models. Independent advice, a strong quantitative orientation, and an international perspective are the hallmarks of our work. For additional information, visit www.senzafiliconsulting.com or contact us at info@senzafiliconsulting.com or +1 425 657 4991.

About the author

Monica Paolini, PhD, is the founder and president of Senza Fili. She is an expert in wireless technologies and has helped clients worldwide to understand technology and customer requirements, evaluate business plan opportunities, market their services and products, and estimate the market size and revenue opportunity of new and established wireless technologies. She has frequently been invited to give presentations at conferences and has written several reports and articles on wireless broadband technologies. She has a PhD in cognitive science from the University of California, San Diego (US), an MBA from the University of Oxford (UK), and a BA/MA in philosophy from the University of Bologna (Italy). She can be contacted at monica.paolini@senzafiliconsulting.com.