Modern Business and Market Perspectives coming from the Progress of the SESAME Project Effort

Ioannis P. Chochliouros[1], Anastasia S. Spiliopoulou[2], Alexandros Kostopoulos[1], Ioanna Papafili[1]
[1]OTE, Research Programs Section
[2]Hellenic Telecommunications Organization S.A. (OTE)
Maroussi-Athens, Greece
[1]*{ichochliouros, alexkosto, iopapafi}@oteresearch.gr*
[2]*aspiliopoul@ote.gr*

Athanassios Dardamanis[3], Ioannis Neokosmidis[4], Theodoros Rokkas[4], Leonardo Goratti[5]
[3]SmartNet S.A., Greece, *ADardamanis@smartnet.gr*
[4]INCITES Consulting S.A.R..L., Luxembourg,
{*i.neokosmidis, trokkas}@incites.eu*
[5]FBK/CREATE-NET, Italy, *lgoratti@fbk.eu*

***Abstract*—Through the advanced coordination and orchestration realised within the wider SESAME project concept, a new architecture has been defined and proposed, aiming to attend several operators/service providers and "engage" them in a modern multi-tenant ecosystem, so that to fully serve the broader vision of the 5G; in particular, this takes place by emphasizing upon the incorporation" of network intelligence and applications in the network edge through NFV and cloud computing and by promoting the effective use of the Small Cell concept. This modern 5G-*based* context influences the related market sector and leads to a multiplicity of business challenges and growth opportunities for the involved actors/players. Moreover, we assess and analyze forthcoming business perspective based on a dedicated proposed business model that strongly identifies the raising potential for growth.**

Keywords—5G; Cloud-enabled Small Cell (CESC); cognitive management; Mobile Edge Computing (MEC); Network Functions Virtualization (NFV); Multitenacy; "Self-x" properties; Small Cell (SC); Virtual Network Function (VNF); virtualization.

I. INTRODUCTION

In a constantly changing telecom environment characterised by the softwarization of networks and the provision of ultra-high speeds, 5G networks are expected to play more than a pivotal role [1]. New players such as functions developers and facility managers enter the market while the role of existing ones will drastically change. Traditional telecom operators will be transformed in order to compete with Over-The-Top (OTT) players. New market opportunities will arise due to lower barriers to entry. Moreover, new advanced applications and services with demanding requirements will be provided, mainly by vertical industries. Charging schemes are expected to evolve due to the use of virtualization revealing more dynamic characteristics. On the other hand, due to 5G networks innovative nature, several challenges should be addressed prior to their deployment and successful adoption. These challenges seem to be multi-dimensional, including not only technical aspects but also societal and economic parameters. Thus, the assessment of these multi-disciplinary factors necessitates a clear technology and business roadmap as well as detailed business models.

Today, communication networks are essential for all areas and sectors of our societies and economies in developed and emerging countries. They support many services and applications of the global Internet. 5G will be required to support an extended variety of capabilities and of anticipated evolutions, affected by the accelerating trend towards massive machine type communications or the so-called "Internet of everything". The next generation of communication systems, as assessed within the "5G" context, will be the first illustration of a truly converged network environment where wired and wireless communications will make use the same infrastructure, thus "driving further" the future networked society [2]. It will offer virtually ubiquitous, ultra-high bandwidth, "connectivity" not only to separate users but also to (Internet-) connected objects. Therefore, it is assumed that the future 5G infrastructure will "serve" a multiplicity of services/applications and domains/sectors. The current SESAME EU-*funded* project (Grant Agreement No.671596) [3] serves a variety of 5G-*related* strategic aims, visions and challenges, as discussed below.

II. THE SESAME APPROACH

A. *Conceptual Vision*

Mobile data traffic and services, fuelled by new demanding personalised applications, radically increase the demand in infrastructure resources so as to keep user experience at a satisfactory level. Up to now, this ever-increasing demand has been fulfilled by the continuously evolving technological framework (3G, 4G), which has offered improved coverage and capacity as well as enhanced resource usage. However, the long anticipated 5G model [4] needs to involve a paradigm shift, that is to establish a next generation network framework achieving reliable, omnipresent, ultra-low latency, broadband connectivity, capable of providing and managing critical and highly demanding applications and services [5]. The fresh, ground-breaking advances in the field are expected to enforce revolutionary changes in network infrastructure and management, offering the power to align with a demanding set of diverse use cases and scenarios. Specifically, one of the envisaged key elements of the 5G technological framework is the capability to deliver intelligence directly to network's edge, in the form of virtual network appliances, jointly exploiting the emerging paradigms of Network Functions Virtualisation (NFV) and Edge Cloud Computing ([6], [7]). 5G network infrastructures should provide rich virtualisation and multi-tenant capabilities, not only in term of partitioning network capacity among multiple tenants, but also offering dynamic processing capabilities on-demand, optimally deployed close to the user. The potential benefits from such an approach trigger the interest of Communications Service Providers (CSPs) such as Mobile Network Operators (MNO), Mobile Virtual Network Operators (MVNO) and OTT content and service providers, allowing them to "gain" an extra share in the telecom market by pursuing emerging business models. Following this direction, novel business cases will produce added value from any kind of infrastructure or application that has the potential to be offered "*as-a-Service*".

While the virtualisation of the communications infrastructure (core/edge segments and access points/macrocells) has been extensively studied by several industry and research initiatives up to now [8], the applicability of this paradigm to Small Cell (SC) infrastructures has received so far very limited attention. The Small Cell concept has become central in today's 4G access; SCs provide improved cellular coverage, capacity and applications for homes and enterprises as well as dense metropolitan and rural public spaces [9]. Their role is "essential" for providing services in populated areas like stadiums, shopping malls, concert venues, and, *generally*, places with (tactic or sporadic) high end-user density. In such cases, usually each telecom operator deploys their own infrastructure, acting complementary to the macro-cell network. Normally, SC provisioning requires a number of time and money consuming procedures as e.g., provisioning of installation site, power supply and so on. Operators must also face the costs of establishing dedicated, high-capacity backhaul connections, not to mention radio resource management and interference mitigation techniques, all translating to extra costs and efforts. However, this static approach based on the ownership of the physical SC infrastructure not only increases operators' CAPEX and significantly hampers business agility, but also is unable to cope with dynamic scenarios. For example, one should consider the case where sporadic flash crowd events arise not only at predefined venues but also at arbitrary areas with minor infrastructure in place, resulting in traffic overflow and signal outage. In order to respond to this "dynamicity", network operators may wish to deploy for some time a Small Cell network to serve e.g., a sporadic flash crowd event, without really owing the underlying infrastructure. The latter could even be provided by a third party, i.e., the owner/operator of the venue. Such sharing scenarios are expected to play vital role in the imminent 5G networks. In order to "address" this need and building upon the "pillars" of network functions virtualisation, mobile-edge computing (MEC) [10] and cognitive management, SESAME's main goal is the development/demonstration of an innovative architecture, capable of providing SC coverage to multiple operators "*as a Service*" [11]. SESAME envisages the logical partitioning of the localised SC network to multiple isolated slices as well as their provision to several tenants. Moreover, in addition to virtualizing and partitioning SC capacity, SESAME supports enhanced multi-tenant edge cloud services by enriching Small Cells with micro-servers.

B. *Development of a Modern Architectural Scheme*

The SESAME Project is an innovative effort to realize multi-tenant cloud enabled Radio Access Network(s) RAN(s), through a substantial change on the architecture of commercial SCs, by evolving them towards the so-called "*Cloud-Enabled Small Cell*" ("*CESC*"). This change paves the way towards "placing" network intelligence and applications in the network edge, with the help of virtualization. Through the advanced coordination and orchestration realised within SESAME, a new architecture has been defined and proposed [12], aiming to attend several operators/service providers and "engage" them in a modern multi-tenant ecosystem [13], to fully serve the broader vision of the 5G. In particular, SESAME proposes the CESC concept, a new multi-operator enabled Small Cell that integrates a virtualised execution platform (i.e., the Light Data Centre (Light DC) for deploying Virtual Network Functions (VNFs), supporting powerful "Self-x" management and executing novel applications and services inside the access network infrastructure. The Light DC will feature low-power processors and hardware accelerators for time critical operations and so it builds a high manageable clustered edge computing infrastructure. This allows new stakeholders to dynamically "enter the value chain" by acting as "neutral host providers" in high traffic areas where "densification" of multiple networks is not practical. The optimal management of a CESC deployment is a "key challenge" of the SESAME context, for which new orchestration, NFV management, virtualisation of management views per tenant, "Self-x" features and radio access management techniques are thus proposed [14]. Moreover, the SESAME effort -with the expected solution(s)- extend the "Small Cell-as-a-Service" ("SCaaS") model, which facilitates a third-party provisioning of shared radio access capacity to mobile network operators in various localised areas, together with the provision of Mobile Edge Computing services [15].

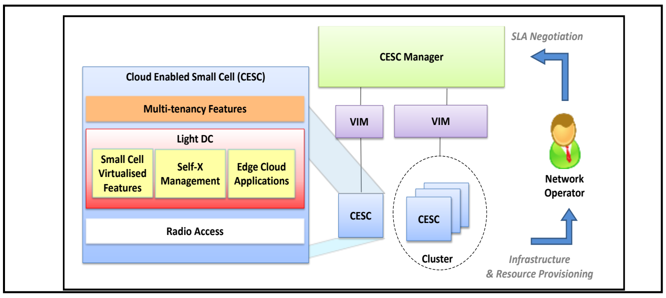

Fig. 1. SESAME high level architecture and main components

Efficient management of resources, rapid introduction of new network function(s) and/or service(s), ease of upgrades and maintenance, CAPEX/OPEX reduction and encouraging openness within the ecosystem, are only a few *-but quite substantial-* examples of the various benefits that the proposed solution can develop and offer for the benefit of the European industry and citizens. After designing, specifying and developing the architecture and all the involved CESC modules, SESAME will culminate with a prototype with all functionalities for proving the concept in relevant use cases.

Fig. 1 provides a higher level view of the initial SESAME architecture; until today and during the course of the project, the architecture has not only been defined in detail, but has also been updated and enriched, *where relevant*. Following to the context of Fig. 1, SESAME introduces and considers the following basic elements: (i) Cloud Enabled SC (CESC); (ii) Light Data Centre (DC) as geographically distributed NFVI (NFV Infrastructure) within the RAN; (iii) Multi-tenant over the RAN, exploiting NFV and MEC concepts; (iv) New business opportunities between the SC infrastructure provider and the mobile network operators; (v) Use of SDN for managing the connections between VNFs (Virtual Network Functions) within the Light DC; (vi) Reuse of the current 4G architecture and protocol stack, taking in mind different possible functional splits, and; (vii) Evolution of "Self-x" properties for more enhanced network and/or service management. For the SESAME evolution, three initial target scenarios have been identified (i.e.: Enterprise services in multi -tenant large business centres; enhanced service experience on the move, *and*; service provisioning in flash events). These have led to a variety of Use Cases (UCs) of practical interest that have all been described and analysed in detail [16]. For the realization of the forthcoming trials and validation works, the most promising 4 UCs with higher impact have been selected.

C. Impact for the Market Sector and Competitive Advantages

SESAME has been conceived to provide the appropriate framework and solutions for Communications Service providers (CSPs) to offer reliable, omnipresent, ultra-low latency broadband connectivity to the customers, "meeting" the highly demanding Future Internet (FI) application and service requirements. The SESAME proposition to realise micro-scale virtualised execution infrastructure included in the CESC devices (i.e., the Light DC) will enable the provision of dynamically repurposed virtual network infrastructures with tailored computing and flexible networking capabilities [17]. This will greatly benefit the CSPs to deploy and offer cutting-edge services to specific customers, with increased cost savings (e.g., energy efficiency thanks to the Light DC design and the portability of functionalities closer to the mobile network edges) and allowing optimal reuse of the deployed virtual infrastructures. Overall, the SESAME project will provide an appropriate framework for European industry to remain competitive in the 5G systems and technology space, enabling the flexible densification of networks and services.

The core contribution of SESAME is to create imaginative and concrete opportunities, for generating competitive advantages for the European ICT market. SESAME is rooted at the core requirement for improving innovation capacity in the European mobile industry by consolidating a very tight convergence of the telecommunications and IT market. This is the "key differentiator" moving towards 5G technologies where the European ICT market will see the emergence of new vertical business segments and services for consumers and enterprise customers. Within this scope, SESAME brings several competitive advantages to the *CSPs and service/application providers (SPs/APs)* including, *inter-alia*:

- Rapid deployment of new services for consumer and enterprise business segments.
- Adding new revenue streams from innovative services delivered from closer to the user, together with offering the user a better service-*oriented* quality of experience (QoE), leveraging the Light DC and the CESCM entities and, *furthermore*, improving revenue opportunities by sharing the infrastructure for specific service providers.
- Introduction of new applications which are "aware" of the local context in which they operate (RAN conditions, localised information, density information, etc.) through the integration of the CESC virtual small cells functionalities [18].
- Drastic reduction of OPEX costs by offloading signaling and management related functionalities closer to the edge and by developing smarter management techniques, and further limiting the TCO (total cost of ownership) / CAPEX costs by promoting shared infrastructures enabled by the multi-tenancy and related virtualised multi-service management framework.
- Flexible development of market innovative and ground breaking services and applications that take advantage of the contextual information provided by the CESC on the radio network conditions and other information at the edges (e.g., edge caching, critical services).
- Creation of new market entrants by "opening up" the shared infrastructures to new software and application providers, infrastructure vendors and other CSPs, thereby increasing revenues and also promoting regulatory support.
- SESAME can also provide competitive advantages to equipment vendors and manufacturers so as to greatly enhance their product portfolio and to develop novel offering in the area of virtualised and cloud-*enabled* small cells platforms.

In addition, SESAME offers competitive advantages also for *IT Service Providers* and *Solutions Suppliers*, as these can get the maximum benefit and advantage out of the SESAME project by being able to closely work with leading mobile market vendors and ICT companies, thus allowing them to strategically position and gain an early-entrant advantage within the industry, also keeping in consideration the rapid evolution of the mobile edge computing.

Involved *SMEs* can acquire different competitive advantages based on their business and market segments and will provide them with unique opportunity to extend their offerings and business advantages towards the 5G landscape.

SESAME will offer fast and cost-effective access to a wide variety of new services and applications to *all European citizens* through a solution that directly supports the specific user and user communities. This among others includes residential and business customers as well as public fixed and mobile users which could ultimately lead companies and business to re-organise their processes, services and practices to increase readiness, productivity and growth, and improve the quality of life of EU residents.

SESAME also contributes to the *community societal challenge* to boost the market opportunities for increased revenues and reduction of CAPEX/OPEX/TCO of telecommunication providers as well as the market positioning of equipment/solution vendors [19]. In addition, SESAME contributes to *"inclusive societies"* by promoting "smart and sustainable growth" and to "strengthening Europe's role as global actor", by bringing innovative solutions to the market validated by industrial partners. Last but not least, SESAME contributes to the *Europe 2020 strategy* by creating a value-added "Europe-on-the-move" society enabling secure and totally accessible mobility opportunities for end-customers and users.

III. BUSINNESS PERSPECTIVES

Market analysis confirmed the dynamic growth of mobile communications and especially of mobile data in terms of traffic volumes and revenues [20]. It has been identified that 4G coverage almost reached its saturation level, whilst 4G adoption is constantly increasing. The results of market analysis indicate that now is the right time to start the deployment of new and innovative solutions such as 5G networks. 5G networks are expected to provide improved performance, high economic and social value [21]. At the same time, 5G networks will arise new opportunities to existing as well as to new players by lowering the barriers to entry and by facilitating the development of new advanced applications. In addition, 5G networks will influence the so called "verticals" that are likely to enter the value chain and generate revenues.

Taking into account the defined SESAME architecture as well as the related use cases, Small Cell Network Operators (SCNOs) are assumed to be the main players in SESAME ecosystem since it will mainly adopt the proposed solutions and tools. Involved market "players"/actors are divided according to their type and then categorized into target groups depending on their relevance to the SESAME ecosystem. These include: end-users and subscribers; IT Equipment vendors; Small Cell vendors; Network equipment vendors; CPE and IoT devices vendors; OTT and e-Service providers; content providers and content aggregators; Network Function Providers (NFPs) and software houses; Facility and Equipment managers; Virtual Small Cell Network Operators (VSCNOs); Small Cell Network Operator (SCNO); Mobile operators; network providers; vertical industries, spectrum owners; regulators; distributors; advertising agencies, and; brokers.

A. Incentives for Adoption

Although the value generation should be specific to each distinct player in the business model, the implementation of the SESAME solution provides the next incentives, *per case*:

For *Operators:* (i) Increase of customer lifetime (avoiding service termination or churn) and ARPU (average rate per unit) by improving QoS and QoE; (ii) increase of sales on slices, *and*; (iii) reduction of CAPEX and OPEX by using NFV.

For *Over-The-Top and (e-)service providers:* Increase of sales on (e-)services delivery (health, security, entertainment, etc.).

For *Equipment vendors and hardware manufacturers:* Increase of sales on equipment and related products (smart phones, sensors, home automation, cars, etc.).

For the *Whole market at country level:* (i) Creation of new market players (new jobs, GDP (gross domestic product) increase) such as network functions developers and facility managers; (ii) acceleration of the time to market, *and*; (iii) deliverance of agility and flexibility.

B. Value Proposition

SESAME offers suitable tools and solutions to Operators and Providers in order to realize the following benefits, as mentioned *per case*: 1) Enhancement of both QoS and QoE, mainly due to improved capacity, low latency and caching; 2) Decrease of energy consumption by moving computation and data at the edge; 3) Improvement of network performance and availability of services because of the inclusion/use of SCs; 4) Improvement of health, saving lives and entertainment through: a) Fast SC deployment in case of natural disaster; b) support of crowd events (festival, meeting, outdoors concert) through small cells' increased capacity, *and*; c) provision of High Definition (HD) streams through caching; 5) Reduction of "rural/urban divide" as SESAME can offer services to locations which lack network coverage (such as rural or mountain areas) through the use of CESC clusters, *and*; 6) Potential for creating new jobs as new players can enter the market (e.g.: network function developers, facility managers).

C. Value Creation Enablers

SESAME creates value by creating tools and providing solutions, such as:

- *CESC:* A micro-server along with the Small Cell forms a CESC. It offers computing, storage and radio resources [22].
- *CESC cluster:* It consists of a number of CESCs and it is capable to provide access to a geographical area with one or more operators.
- *CESCM (CESC Manager):* It is the central service management and orchestration component in the overall architecture, integrating all the necessary network management elements and the novel functional blocks
- *"Self-x" features:* Self-planning, self-healing and self-optimization functions etc. [23], leading to the automated operation of CESCs.
- *Virtualised execution environment (Light DC):* It provides the opportunity to chain different VNFs to meet a requested network service by a tenant (i.e. mobile network operator).
- *Edge computing capabilities:* This implicates for acceleration, virtualization, caching, etc.

- *Multi-tenancy:* Multiple operators are sharing the same infrastructure mainly through slicing / virtualisation.
- *Reduce the average service creation time:* The flexible design of the CESC platform and the associated management layers promote a shared virtualised infrastructure, i.e., a cloud environment, right at the network's edge. This allows multiple services, as for example VNFs, to be deployed at a lower time scale.
- Contribution to standardization.

In order to summarize value proposition/creation along with SESAME results and features, the Table I is derived.

TABLE I

SESAME Result	***Feature***	***Value***
CESC Platform	Its flexible design and the associated management layers promote a shared virtualised infrastructure, i.e., a cloud environment, right at the network's edge	Reduces the average service creation time
CESC Cluster	Provides access to a geographical area with one or more operators.	Reduces rural / urban divide
Edge Computing Capabili-ties	Acceleration, optimization, virtualization, caching, "Self-x" features	Reduces energy consumption; Improves QoS/QoE; Improves network performance; Automates operation; Reduces OPEX;
Multi-tenacy	Infrastructure sharing mainly through slicing /virtualisation	Reduces CAPEX
Virtualised execution environ-ment (Light DC)	VNFs chaining to meet a requested Network Service by a tenant	Reduces CAPEX/OPEX

The next step is to define the relationships between the distinct actors in the SESAME environment. The proposed model involves many different players and a complex value network. The reference model is depicted with all the participating players, relationship interfaces, revenue streams and cost drivers in Fig. 2. Some essential definitions for its comprehension are given as follows: a) The direction of the arrows in the model represents the direction of service flow; b) Revenue flow is considered to be in the opposite direction. In some cases, revenue sharing exists between two players, resulting in a bidirectional flow, *and*; c) The ellipse represents a group of players/roles. Each player/role is depicted in rectangular boxes within the ellipse.

This reference model describes a basic SESAME scenario for the delivery of services from one operator to another as well as from the operators/providers to end-users. In the latter case, end-users subscribe for these services. Hence, SCNOs is assumed to be the main SESAME player while, in general, operators/providers "act" as the main responsible players towards the subscriber providing telecom services like voice and video telephony, broadband access, etc. In this model, the following type of service level agreement exists between subscribers and operators or service providers: A subscriber enters into a contract or service level agreement (SLA) with the operator -or the SP- for the usage of services. The contract can be of two types: post-paid or pre-paid, based on the mode of subscription payment. A service provider may adopt different pricing models to charge for the services provided. The billing service is taken care of by the service provider, thus incurring OPEX.

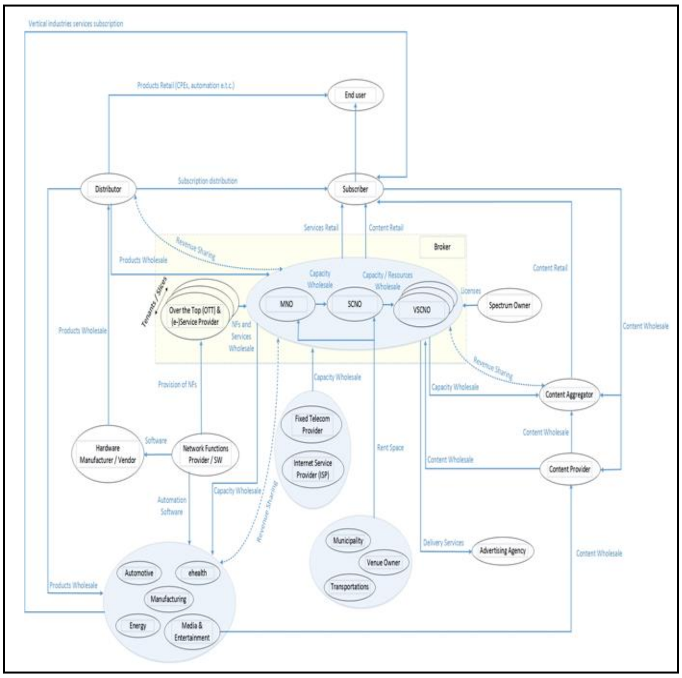

Fig. 2. SESAME business model

The CPE (Customer Premises Equipment) distribution is directly taken care of by the CPE vendor, as the usual distribution method. Here, CPE vendor and the operator may have equal or higher power with respect to each other based on the control over the CPE distribution network and the subscriber base, *respectively*. Revenue sharing deals may exist between the distributor and the operator (e.g., for subscription distribution). Likewise, some of the Vertical Industry's services can be offered to the user through a distributor. As far as the provisioning of content is concerned, it can be done either directly by content providers or aggregator or by the operator. In this case, the operator purchases wholesale content from various content players (such as content providers and producers) and thus takes up the additional role of a content aggregator. The operator is the key player in this case having a direct relationship with the subscriber base, providing content through a portal and billing the subscriber for the services. By assuming the role of content aggregator, the operator can gain greater control of the value network. This is also known as "vertical bundling". The other case is that a third party such as the content aggregator provides content to the subscribers by using the operator's network capacity. Thus, the operator resells a part of its capacity to the content aggregator. The content aggregator, in turn, has to pay for the capacity usage to the operator. A revenue sharing model can also exist between these players for content usage. These revenue models may differ depending on the type of content provided. Alternatively, users can have a contract with both the operator and the service provider.

The content provided can be of different types. Examples of content include news, entertainment, video, audio, etc. Value-added services can also be provided through the operator by other players. Such services include location-*based* content, presence services, banking info/alerts, sports/match alerts, travel/transportation alerts, weather alerts, missed call alerts, contests and voting, online payment services, etc.

The business prospects of the operator can be further enhanced if there is collaboration with an advertising agency by selling paid placement inside data feeds. The operator can opt to have contextually targeted overlay ads that will run on e.g., videos. In the described case, advertising campaigns produced for the clients of the advertising agency can be delivered via the operator's content, for which advertising delivery the advertising agency pays the operator. Similar collaborations also exist between advertising agencies and content providers or OTT.

Similarly, collaboration with vertical industries will allow revenue sharing. For example, the companies involved in the health care industry and the domiciliary care provide services to subscribers using operator's network capacity. In particular, the operator resells a part of its capacity to the health care provider. The health care provider in turn has to pay for the capacity usage to the operator. A revenue sharing model can also exist between these two players.

IV. CONCLUSIONS AND OVERVIEW

In this paper we have identified, in brief, the essential innovative features coming from the original SESAME architecture and related platform evolution, by emphasizing upon the various -and multiple- business opportunities and potential benefits for the involved market actors. SESAME offers the possibility to create strong impact in the market as well as to provide significant perspectives for growth to the involved players coming from various potential areas/sectors. In addition, we have discussed incentives for SESAME adoption, together with value proposition and creation, as resulting from the latest evolution of the project. As a step further, we have presented a dedicated business model and we have provided details regarding the involved actors, their interrelations and corresponding revenue streams, *inter-alia* by highlighting the significant roles of contents providers, brokers and verticals so that to realize most of the SESAME business potential expectations. It is assessed that due to its innovative features, SESAME can offer market innovation and growth.

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