5G ecosystem dilemmas: sharing roles and revenues

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Abstract—**This paper introduces the platform ecosystem approach and applies it in a 5G setting. It seeks to answer successful strategies to decision dilemma of collective action in a context with high dependency between actors. We develop a model for a duopoly case where two 5G platform ecosystem exist and suggest six scenarios which combine compatibility between 5G platforms and Mobile Network Operators' (MNOs') willingness to share market in the total ecosystem. We show that under certain market conditions, MNOs will be more profitable by allowing 5G platform compatibility and that there are several realistic cases where showing moderation in capturing market shares is their best strategy.**

I. INTRODUCTION

The new concept of network slicing has been a central idea for efficient utilization of scarce network resources and the adoption of new business models by Mobile Network Operator (MNOs), such as network slicing-as-a-service (NSaaS) and Infrastructure-as-a-Service [1]. Given the limited resources of MNOs and the wide range of vertical domains disrupted by 5G technologies, the envisioned economic growth and social impact [2] cannot be realised by MNOs alone. The expertise of a wide range of third-party software/service providers, integrators and consultants is needed for vertical enterprises to transform the superior performance of 5G in terms of throughput, delay, mobility and security into increased cost effectiveness and/or new products/services. Furthermore, supporting such external entities by providing access to anonymized data, advanced billing systems and other business support systems can create additional revenue streams for MNOs. Nevertheless, there is not much research on what a 5G ecosystem means business wise, and obstacles and enablers for success. Moreover, most 5G ecosystem articles have a technological focus

This paper asks: which strategies should a mobile network operator choose, when providing a 5G platform and having high profit and growth ambitions. We envision a future platform ecosystem where 5G is the platform, and all the other IT providers in the ICT industry are the platform complementors. This implies that we are black-boxing the complex operation of the MNO itself, and focus on its relationships to other MNOs and IT providers as complementors. Together, the 5G platform and IT complementors serve enterprise customers from different verticals, e.g. the health vertical.

In our study we illustrate a 5G platform's painful consideration of leaving substantial market shares to its IT complementors, itself aiming for a smaller share of a larger market. We also consider the similarly painful considerations of choosing compatibility as a strategy between MNOs. We explore this topic logically, supported by insight and data from the Norwegian market.

II. PLATFORM ECOSYSTEM

A core idea of platform ecosystems is that a platform seeks to govern the ecosystem and exposes core services that allow other actors to innovate with and provide value-added services. To kick-off self-reinforcing effects and spur the high growth in the total ecosystem, it is vital to have an open platform and allow for satisfying levels of profit for other roles and actors [3]. It is acknowledged that there is a tension between the goal of triggering innovations and growth in the market as a whole, and the goal of extracting sufficient levels of profits for the platform. This challenge concerns partnership models and relationships, and not technology, acknowledged in recent and previous ecosystem and telecommunication literature [4, 5].

Technological interoperability between platforms and complementors, often referred to as application programming interfaces (APIs), is a prerequisite for the evolving ecosystem. Moreover, organizational interoperability is also required in the form of aligned business process, referred to as for instance legitimation and risk sharing [3].

Thus, the platform ecosystem concept touches on a well-known dilemma in settings where the total result is dependent on more actors. Theories of collective action explain that in such settings collaboration may and may not happen and elaborate on the circumstances where collaboration will happen [4]. The causes of non-establishment of collaborations are not technological limitations but ability to establish stable institutions and governing mechanisms, as well as trust and belief in business opportunities for all.

Technological modularity is an underlying characteristic of an ecosystem where more roles jointly create and capture value [6]. High complementarity between modules implies that they create value only when delivered together. Thus, the roles, actors, and technologies are distinct, yet interdependent. Often, an ecosystem is referred to as an established market with core actor surrounded by many smaller actors, or a platform and its complementors [3]. The Android and iOS mobile ecosystems are often used as examples, and recently also 5G [6].

III. 5G - AN EMERGING ECOSYSTEM

In this paper we explore NSaaS as the platform in an 5G ecosystem. We assign the complementor role to all those other IT firms in the ICT industry. The 5G platform is dependent on other IT complementors providing advanced ICT-solutions to the enterprise customer in the vertical. IT complementors are typically: system integration, consulting, software, data hosting (data centres), cloud services, devices, and sensors.

In this paper, we understand that from an MNO's point of view, a network slice is an independent end-to-end logical network that runs on a shared physical infrastructure, capable of providing a negotiated service quality. This allows the provisioning of NSaaS contracts (instantiations), which represents the instantiated set of resources customized to accommodate the performance requirements of a particular application for one particular enterprise customer. Devices and user equipment (UE) are authorized to access this NSaaS contract. One UE can access multiple contracts simultaneously. In plain words this means that the SIM-card in one UE can connect to many different NSaaS contracts, on top of the mobile broadband subscription to a home mobile network [7].

The above assumptions lead to a new emerging 5G ecosystem model. One example including these elements could be a hospital providing a health-critical application for clients. The hospital clients could potentially have mobile subscriptions with SIM cards from different MNOs. In this setting there will be a need for ubiquitous connectivity and mobility, interoperability and roaming between MNOs. One MNO has to develop and share the market with other MNOs and IT complementors, compared to a model where one MNO mainly develops and provides services within its own network footprint and keeps the market to itself.

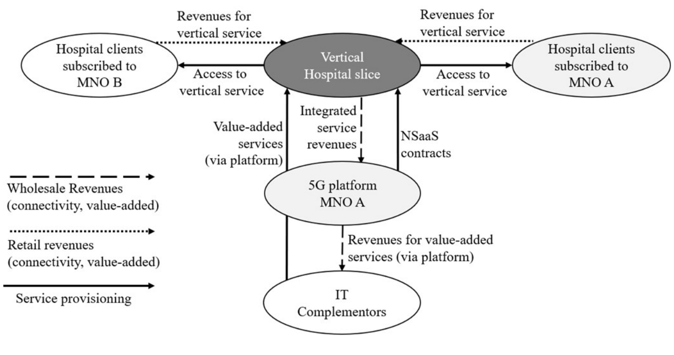

Fig. 1. Illustration of 5G platform ecosystem and two-sided market

More specifically, it is meaningful to describe the 5G case illustrated as a two-sided market, see Fig. 1. In our case the 5G platform – or focal MNO A – is the provider of NSaaS and offers NSaaS contracts to vertical customers. Thus, one side of the market is a vertical customer, for instance a hospital, which purchases a wholesale NSaaS contract for specific application from MNO A. Another side of the market is the IT complementors, i.e. SW providers, system integrators, consultants, etc. that provide a service to the hospital via the platform, or directly. Furthermore, the hospital clients that must be allowed into the hospital NSaaS contract via their SIM-card in order to use the hospital applications with the required network capabilities. The MNO NSaaS provider – here MNO A – must arrange the delivery NSaaS contract to the hospital, but also ensure that all the hospital's clients can access vertical applications via the clients' own mobile subscriptions and installed SIM-cards. These mobile subscriptions could be from another MNO – the MNO B. The hospital has an independent relationship with the client at the retail level.

In our case we suggest that the hospital pays the selected MNO for the integrated solution, i.e., allowing their clients to access the NSaaS and value-added services regardless of their home network. Then the MNO in question, i.e., MNO A, would distribute a share of the revenues related to *value added services* to all other IT complementors. The rest revenues constitute the new type of income for MNOs beyond pure connectivity. As mentioned, MNOs' objective with 5G is to grow their markets through adding more value, that is, moving into consulting, system integration, hosting and software. Thus, it is a delicate question how to share the market for value added services between MNOs and IT complementors. Note that MNOs revenues from mobile subscriptions are not shown in the figure for better clarity.

IV. A GAME-THEORETIC ANALYSIS OF MNOS' DILEMMAS

In this section we assess the incentives of two competing MNOs in deploying and running interoperable platforms, as well as, guaranteeing that a wide range of value-added services will be made available from each individual platform. We pinpoint the dilemmas of each MNO in a market where the logic of a platform ecosystem is present; while they compete for attracting complementors on supply-side and verticals on demand-side they also benefit from each other's presence. In order to do so, we characterize the Nash equilibria for different market conditions.

Each 5G platform hosts composite services, comprised of 5G slice instances and advanced software solutions, which are tailored to the needs of enterprise customers in several domains/verticals. The NSaaS contracts offered by each MNO can differ in key aspects such as 5G coverage, customer support, etc. and thus vertical customers are assumed to have preferences on which MNO to connect to. Similarly, the software systems are usually developed and marketed by third parties, who have significant expertise in meeting the needs of different market segments. For example, some solution providers focus on the health domain (or even at certain types of health services), while others may specialise in the utilities sector.

Thus, in the general case, vertical customers have preferences for both communication services, as well as, digital services. To what extent their preferences are met will depend on the strategic decisions of MNOs and IT complementors alike. In the following we will analyse the choices of those actors and how these can lead to different market outcomes.

A. The MNO strategies

We focus on a duopoly scenario where two 5G platform ecosystems exist; each one operated by MNO A and B, respectively. For simplicity, and without loss of generality, we assume that these operators have equal market shares in the retail mobile connectivity market, i.e., end-customers.

The first decision MNOs need to take is what technologies will be adopted, e.g., for service orchestration and Network Function Virtualization. We assume that several variants are present from different standardization organisations and one of the MNOs, for instance MNO A, is involved in those activities. Thus, MNO B can choose 1) the same technology as MNO A or 2) a different one. Suppose that these technologies are functionally equivalent and compatible with lower-level resources at different network domains, e.g., radio access network, transport, core of both operators. Thus, in this context, MNO B will choose the preferred technology as a leverage for market dominance rather than based on performance criteria, or cost-wise.

The second decision involves the relationship inside a single platform ecosystem. Each MNO can 1) pursue a dominant role in the platform ecosystem by asking a large share of the revenues for value added services, or 2) enable a platform ecosystem where distinct but interdependent IT complementors are encouraged to offer advanced services while paying low royalties to the MNO. Asking the lion's share from the value-added services market, increases MNOs' revenues but discourages IT complementors from offering their advanced services and eventually shrinks the market. Instead, to build a high-volume market the MNO should signal willingness to share most revenues with IT complementors. It should open its technology for, and take advantage of, higher volume of innovation. An MNO must build complementors' trust in market roles and profit opportunities so that they are willing to invest and engage. Note that while it would be relatively easy and feasible to change revenue sharing policy, we assume that MNOs do not abandon their strategy.

The third decision is whether an MNO should compete with IT complementors in developing and provisioning value-added services. We assume that if a single MNO follows an aggressive revenue sharing policy, then she takes on the role of a digital service provider as well and become a vertically integrated provider (see next section for the justification). As we will examine later, such a strategy can be meaningful for operators with recognisable brand name that can attract a significant share of enterprise customers in vertical domains.

B. The decisions of IT complementors

We assume that several digital service providers operate in the market and each one of them must choose the (single) technology to be used during the design and development phase. This decision takes place after the MNOs have chosen their strategies above. We assume that IT complementors select the more generous MNO, i.e., the one that asking the lowest royalties. If both MNOs follow the same revenue sharing strategy, then they choose randomly one of them.

There are two main reasons for not replicating their solution in both platforms. The first is that they would face increased development, testing and provisioning costs. Even though these technologies are functionally equivalent, the use of different APIs, templates etc. will affect how complementors design and develop their software to support the appropriate interfaces to 5G backend systems, describe virtual services and/or generate software images among others. The second reason is that there are cases where the digital service provider in question shall be able to serve (some) end-users, e.g., hospital clients, even though the latter are subscribers of the unsupported MNO. For example, the customers that are locked-in to the digital service provider can become multi-homed by downloading a new eSIM profile on their device from the other MNO.

C. The decisions of enterprise customers in verticals

Inspired by the approach followed in [8], the superset of enterprise customers (e.g., hospitals in the health vertical, car manufacturers in the automotive industry, etc.) represents the maximum market size. To what extent the full market will be served, or not, depends on the number of verticals that are willing to pay the (fixed) price for each available bundle of connectivity and value-added services, which is assumed to be the same for all offerings.

D. The scenarios

We establish the following six scenarios based on the possible strategy combinations of the two MNOs:

(1) Incompatible and aggressive platforms, i.e., both MNOs ask high share of revenues from value-added market and choose different technologies resulting in poorly developed 5G market;

(2) Incompatible but innovation-supportive platforms, i.e., both MNOs ask low revenues share from value-added market, while adopting different technologies;

(3) Compatible and aggressive platforms, where both MNOs choose the same technology and myopic revenue-sharing policy;

(4) Compatible and innovation-supportive platforms, where both MNOs choose the same technology and follow a forward-looking revenue-sharing policy that maximises the potential impact of 5G to the various sectors of the economy;

(5) Innovation-supportive platform vs. vertically integrated provider, where a) MNOs choose different technologies and, b) the first one acts as a platform while the other one does not, and

(6) Innovation-supportive platform with compatibility vs. vertically integrated platform, where the MNOs choose the same technology and thus IT complementors can make their solutions available to vertical organisations attached to the second MNO at no cost.

E. Estimating market size and MNO revenues in each scenario

For each scenario the market size in terms of subscriptions captured by both platforms depend on the interoperability decisions of the MNOs and the willingness to pay of the indifferent customers. The latter differs in order to reflect the consequences of MNOs' rational choices on the growth potential of the 5G market. In particular we assume that the market size for scenario $i = 1,\ldots,6$ is given by the formula $m_i = 1 - (s_i * c)$, where s_i represents the number of factors that have a negative effect on the vertical organisations' willingness to pay and c is a constant scaling factor. In particular, s_i is the sum of the number of MNOs following an aggressive revenue sharing policy and a binary value representing the presence (or not) of incompatible platforms. For example, $s_4 = 0$ because in scenario (4) no MNO is aggressive and the same technology is adopted. This means that market size for scenario (4) is $m_4 = 100\%$. Working on a similar manner we get $s_1 = 3$, $s_2 = 1$, $s_3 = 2$, $s_5 = 2$ and $s_6 = 2$. Market size for each of those scenarios can be computed by considering different values for c, for example from 0.01 to 0.30.

In the following we will estimate the market size in an ideal case where all (100%) subscribers connect to several vertical applications via a separate 5G slice. The base case is the Norwegian market [9] where about 5.7 mill subscribers were present in 2017 and an additional 1.57 million devices belonging to the Internet of Things. We assume that in the ideal scenario each subscriber and device/sensor is connected to 7 and 1 slices respectively at the same time, while connecting to a slice triggers a payment of NOK 91 yearly per slice. Then the total annual connectivity revenues generated for both MNOs are estimated about NOK 3.8B. We assume that the slice connectivity revenues constitute 10% of the total 5G market. Thus, we can calculate the total market to be about NOK 37.9B, while the market for value added services to account for NOK 34B. Now, each platform is assumed to capture 10% from value added services revenues (or NOK 3.8B) under the "Low MNO share" strategy and 50% in the "High MNO share" case (resulting in NOK 17B). The rest revenues from value added services are allocated to complementors, who are not entitled to any connectivity revenues. In the case of a vertically integrated MNO, the digital services provisioning department is assumed to attract a low (5%) or significant (25%) share of enterprise customers in vertical domains, which is denoted with v.

F. Characterizing equilibrium strategies for MNOs

Based on the assumptions above we can calculate the total revenues of MNOs in each one of the six scenarios outlined above. Given that these MNOs compete to attract enterprise customers from several vertical domains and that each one's decision will affect the economic performance of the other, we follow a game-theoretic approach. We seek to identify the best-response strategies under the Nash solution concept for different values of the scaling factor c and the share of enterprise customers in vertical domains obtained by a vertically integrated MNO. In other words, what strategy brings the highest revenues to an MNO if the opponent had no reason to change strategy. Table 1 shows the total annual revenues for MNO A and MNO B for all four strategy combinations, if they had chosen incompatible technologies, while Table 2 does so in the case of compatible platforms.

Table 1 Total annual revenues (in NOK) for MNO A and MNO B for different revenue-sharing strategy combinations in the case of incompatible technologies (c=0.15 and v=5%)

		MNO B	
		Aggressive	Forward-looking
MNO A	Aggressive	**880,367** **880,367**	451,582 713,025
	Forward-looking	713,025 451,582	**700,898** **700,898**

In both tables we observe that there are two Nash equilibria states; both MNOs will either choose the Aggressive revenue-sharing strategy or the Forward-looking one (marked with bold). The reasoning is the following. Suppose that MNO A plays "Aggressive", then MNO B should respond with "Aggressive" as well (since NOK 880,367 > NOK 713,025). But, if MNO A plays "Forward-looking", then MNO B should follow the same strategy as 700,898> 451,582. Note that the first strategy combination would bring higher revenues to each MNO, but the second equilibrium is probable as well. A similar pattern appears in Table 2 for the case of compatible technologies.

Table 2 Total annual revenues (in NOK) for MNO A and MNO B for different revenue-sharing strategy combinations in the case of compatible technologies (c=0.15 and v=5%)

		MNO B	
		Aggressive	Forward-looking
MNO A	Aggressive	**2,310,200** **2,310,200**	1,078,683 1,703,183
	Forward-looking	1,703,183 1,078,683	**1,571,565** **1,571,565**

By comparing the two tables, we observe that the revenues of MNOs if they had chosen compatible technologies are higher than in the case of incompatible ones. Thus, a rational MNO B would always choose the same technology with MNO A.

Note that the payoffs above are produced for moderate scaling factor value ($c = 0.15$) and share of the added-value market by the vertically integrated MNO ($v = 5\%$). Fig. 2 presents the revenues per MNO at the equilibrium for different values of the scaling factor c, assuming that the vertically integrated MNO has low share in the value-added market. We observe that using compatible platforms (shown as green curves) yields higher profits than incompatible ones (represented with red colour) for MNOs in a consistent fashion. Furthermore, choosing aggressive revenue sharing schemes is a candidate equilibrium outcome for scaling factor $c < 0.19$, i.e., in market scenarios where vertical customers are less sensitive to the decisions of MNOs. On the other hand, asking lower royalties remains a best-response strategy for higher scaling factors also. Finally, non-symmetric strategies remain dominated by symmetric ones and thus do not appear in the figure.

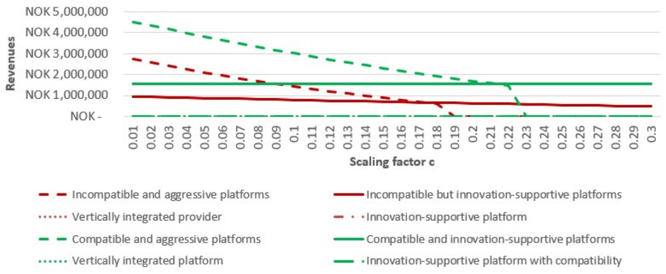

Fig. 2. Nash equilibria strategies and total MNO revenues for different scaling factors in the case of low market share of vertically integrated MNO in the value-added market

Fig. 3 presents the revenues per MNO at the equilibrium for different values of the scaling factor c, assuming that the vertically integrated MNO has significant share in the value-added market ($v = 20\%$). Choosing compatible technologies remain a dominant strategy even though incompatibility cannot be excluded. However, in contrast to the previous figure, we observe that being aggressive is the only equilibrium revenue sharing strategy for low values of scaling factor c. Furthermore, for moderate values of c, the MNO with better access to the vertical organisations chooses to become a vertically integrated provider (or platform), while the best response of the other MNO is to support innovation by third parties (shown with the dash-dot curves). Finally, for high values of c we observe that if incompatible technologies prevail then low-sharing revenue sharing agreements is an equilibrium strategy for both MNOs.

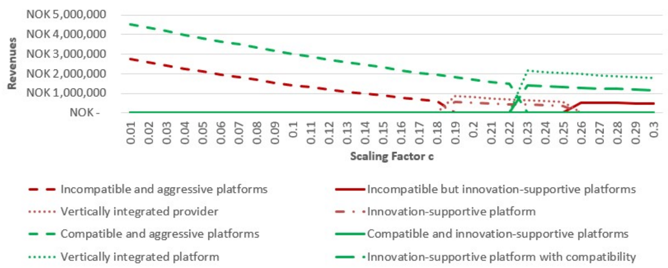

Fig. 3. Nash equilibria strategies and total MNO revenues for different scaling factors in the case of high market share of vertically integrated MNO in the value-added market

CONCLUSION

This paper describes an example of a 5G platform ecosystem. The purpose is to illustrate the dilemmas an MNO faces when considering sharing 5G market shares with IT complementors in an ecosystem. First, describe the 5G market as a platform ecosystem where MNOs provide the 5G platform, and IT firms are the complementors, providing respectively connectivity and value-added services. Second, we discuss that MNOs have the incentive to choose compatible platform technologies, while there are market conditions that render innovation-friendly revenue sharing agreements as the natural choice of MNOs, without the need for regulatory intervention.

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