International coordination in 4G licensing

Final project
Social and Economic Networks

Ivan Vallejo

June 23, 2017

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1 Introduction

Mobile-cellular services have witnessed unprecedented growth in the last decade. Indeed, double-digit growth rates in mobile-cellular penetration were maintained until 2011.[1] After that year, growth has been driven by the substitution of older mobile-technologies with newer ones: from 2G to 3G and from 3G to 4G (Figure 1).

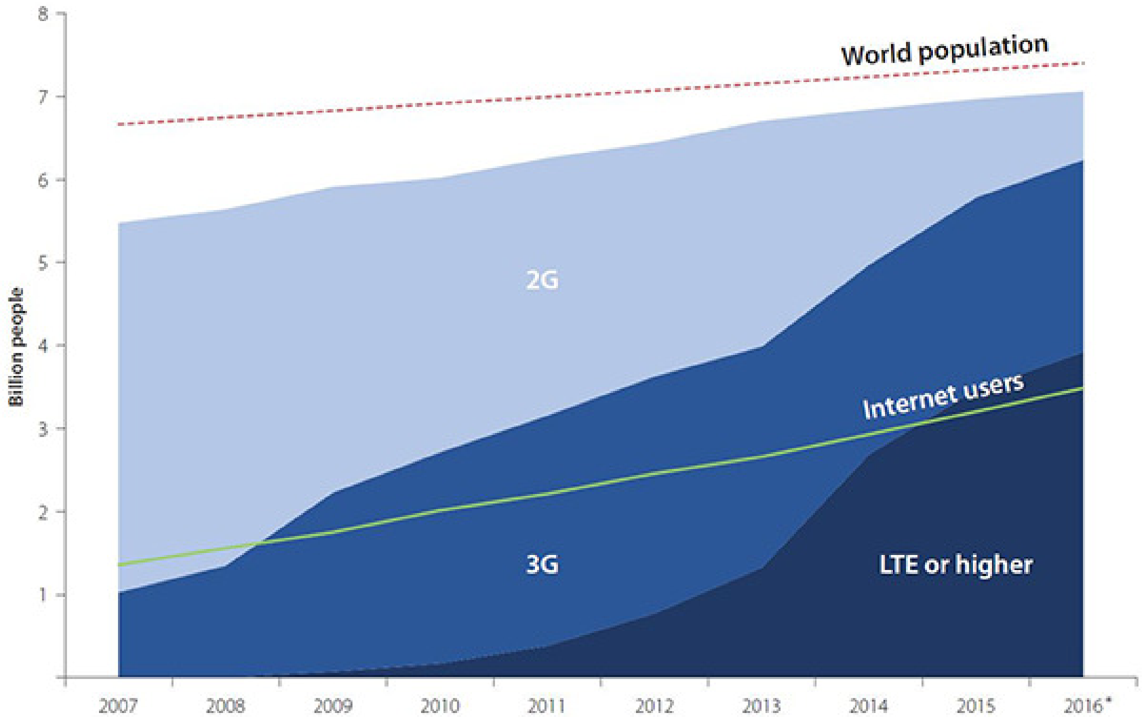

Figure 1: Evolution of the population covered by each mobile technology, 2007-2016.

Note: LTE or higher refers to 4G.
Source: International Telecommunication Union (2016).

This projects looks into the dynamics of the diffusion of mobile-cellular services. In particular, it focuses on a specific element of the international coordination of government policies concerning 4G diffusion: the decision made by each country to allocate, assign and clean (whenever necessary) the spectrum for the new technology. These public interventions are a prerequisite for the service to become available and are generically referred to in this project as "4G licensing".

Based on data about 4G launch dates, and the global network structure defined by countries'

[1] Source: International Telecommunication Union.

similarities, this project tests for network effects on the licensing dates.

2 Literature review

2.1 Mobile services and network industries

Mobile services are a paradigmatic case of network industries. In the context of antitrust and competition law, network industries have been studied in detail because of some particular characteristics which lead to specific competition dynamics.

The following salient features of network industries need to be considered when analyzing the regulatory/policy initiatives undertaken in the mobile arena:

- Networks are composed of complementary nodes and links: a service delivered over a network requires the use of two or more network components. Moreover, **network effects arise because of complementarities**. For example, at least two nodes are required to make a mobile phone call and the higher number of nodes (people I can call), the higher the utility for the users of the network (Economides, 2008).
- Mobile services can be seen as two-way networks in which each additional customer provides **direct externalities** to all other customers in the network. That is, the (n+1)th customer adds 2n potential links to the network, thus increasing its value (Economides, 2008; Kauffman and Techatassanasoontorn, 2005).

The characteristics above explain a range of particular features of markets with network effects. In particular, the following features are of relevance when considering technology diffusion in mobile markets (Economides, 2008):

1. **Fast network expansion:** the self-reinforcement of network effects leads to much faster expansions than in markets with no network effects. The uptake of the service follows an S-shaped curve, approaching the saturation limit faster than in markets with no network effects (Figure 2).

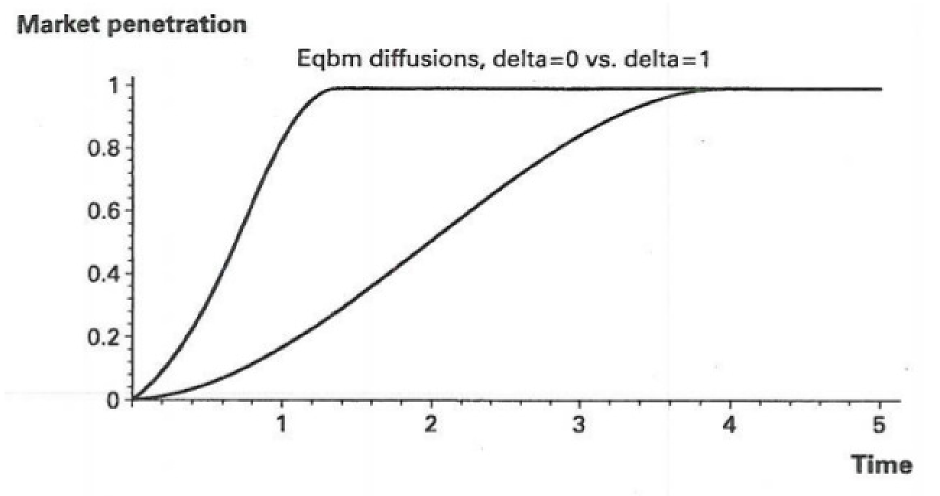

Figure 2: Expansion curve with and without network effects.

Source: Economides (2008).

2. **Free entry does not lead to perfect competition:** In markets with strong network effects (as the market for mobile services), once few firms are in operation, the addition of new competitors, even under conditions of free entry, does not change the market structure in any significant way. For instance, mobile markets are framed by the spectrum assignment to mobile network operators, currently about three or four players per country. However, in most OECD countries there is no limit to the number of subsequent licences given to additional mobile service providers, who can offer their services in the form of mobile virtual network operators. Nevertheless, in line with the theoretical findings in Economides (2008), in practice most of the market share is concentrated in three or four players (OECD, 2014 and end-2011 OECD statistics).

3. **Standards:** It is the compatibility of standards that makes complementarity (and therefore network effects) real. On the one hand, compatibility with competitors brings higher benefits because of network externalities. On the other hand, it makes products closer substitutes and therefore increases competition and reduces benefits. This paradox may give rise to coordination games or other types of games depending on the strategy adopted by each player. Moreover, since mobile technology has a global dimension,[2] coordination involves a large number of players with often conflicting interests. The history of 1G, 2G and 3G is rich in examples of how conflicting institutional logics and stakeholders' interests led to coordination pitfalls (Cowhey et al., 2008).

[2] Radio-frequencies are transmitted over borders and require coordination between countries in order to avoid interferences. Standards require interoperability to allow connections between operators and countries. Affordable telecommunication equipment depends on global economies of scale, which are only possible with international standards.

In the context of mobile services, the points above can be summarized into two important questions determining market expansion: When is a new standard (2G, 3G, 4G) introduced in the market? Which is the market structure at the early stages, right after the introduction of the new standard?

This latter question is relevant because of point (2) above: once a few firms are in operation, the addition of new competitors has little impact on the market structure. Therefore, the timing in entering the market is of paramount importance.

2.2 International diffusion of mobile services

Mobile services have spread worldwide in successive technological waves (Figure 1): from analogue(1G) to digital (2G); from voice-centered services (2G) to data-centered services (3G); and currently from regular-speed data transfers (3G) to all-ip high-speed communications (4G). Standardization bodies are currently discussing the specifications of the next wave (5G), which promises to bring the Internet of Things into the mobile ecosystem.[3]

Each technological wave may lead to a distinct market structure. Disruption does not only come from the nature of the services enabled by the new technology (e.g. voice only in 2G compared with voice and data in 3G), but also because of the government intervention needed to transition from one technology to another.

Indeed, radio-frequency spectrum is a scarce resource and needs to be allocated for each technology and assigned by the national regulatory authorities to chosen market players.[4]

From the experience gathered in the transition from 1G to 2G, and from 2G to 3G, the following factors can be highlighted as playing an important role in the diffusion of mobile services:[5]

- The diffusion of successive generations of a technology produces two effects: diffusion effects (how a technology is adopted over time) and substitution effects (how a new technology replaces an early one over time). As a result of the interplay of these who effects, the installed base of an earlier generation of technology may have a positive

[3] See for instance Aminata A. Garba's overview on 5G at 14th World Telecommunication/ICT Indicators Symposium which took place in Botswana in November 2016.

[4] In some cases, spectrum *refarming* has been allowed. That is, regulatory authorities have authorized mobile operators to re-use part of the spectrum that they used for an older technology for deploying a newer technology. For an example, see Directive 2009/114/EC that prompted the *refarming* of 2G spectrum for 3G use in the European Union.

[5] This is not an exhaustive list of all factors that influence the diffusion of mobile services. Rather, among the most important factors, those which may be related to the topic of this project (international coordination in 4G licensing) are highlighted.

impact on the diffusion of a later generation of technology, as in the case of 1G and 2G (Kauffman and Techatassanasoontorn, 2005; Koski and Kretschmer, 2005), or have a null or negative effect, as in the case of 2G and 3G (Bohlin et al., 2009).

- The spectrum capacity made available and the regulatory practices governing market entry (e.g. timing and number of licences) have a significant impact on the expansion of a given mobile technology. The evidence of these effects has been well documented for 1g and 2G global adoption (Gruber and Verboven, 2001; Kauffman and Techatassanasoontorn, 2005; Koski and Kretschmer, 2005).
- As countries adopt a given mobile technology, the likelihood of "similar" countries adopting the same technology increases, so that the timing of first entry resembles an epidemic model of technology diffusion (Dekimpe et al., 2000; Sundqvist et al., 2005).
- The coordination games played by countries during the different waves of mobile technologies are complex. For instance, countries may have an incentive to coordinate with their regional neighbors for several reasons (e.g. radio-frequency and standards harmonization). They may also have an interest in being among the first adopters of a given technology. Along these lines, 3G licences were assigned in a majority of European Union countries coordinately in the 2001-2003 period, well in advance of most other regions in the world. However, the result was not positive: after several technical and commercial problems, the widespread service roll-out in the European Union was pushed back to 2006 (Cowhey et al., 2008). Other studies have found that lag countries learn from lead countries that have already adopted a mobile technology (Dekimpe et al., 2000; Sundqvist et al., 2005). This suggests that late adoption may also be a good strategy in some situations.

The points above suggest that there may be network effects in the international coordination of government policies enabling mobile diffusion, although their theoretical modeling might be difficult given the many determinants affecting each country's decision.

3 Data and methodology

3.1 Data

The latest data from the Global mobile Suppliers Association (GSA) on LTE deployments worldwide were used as a proxy for 4G licensing dates (Global mobile Suppliers Association, 2017).

In particular, the date of the first commercial launch of LTE services in each country was taken as the proxy for the licensing date (Figure 3). This should be an acceptable approximation for the purposes of this project given that our analysis does not rely on the precise date of assignment.

Indeed, coordination between countries may already start with the announcement of the licensing in neighboring countries. That is, it is not from the effective licensing date that neighboring countries start coordinating, but all throughout the announcement period, which can roughly span over a year.

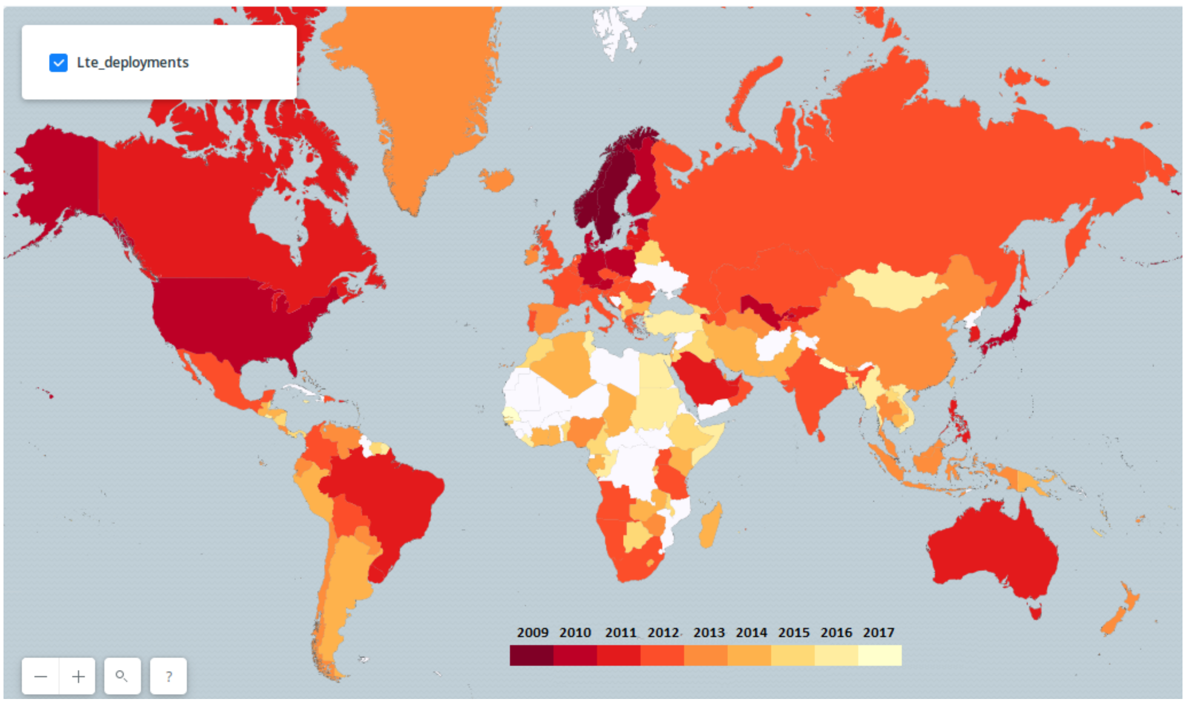

Figure 3: LTE commercial launch dates, by country and by year.

Source: Author based on data from Global mobile Suppliers Association (2017).

Another assumption we are making is that the first LTE commercial launch is also the first 4G deployment in a country. Indeed, 4G is a broad term used differently by the industry (which definitely counts LTE in 4G) and by international standardization bodies (e.g. ITU does not consider LTE in 4G).

It is out of the scope of this project to discuss the classification of 4G. The term is just used in this report as meaning "the next wave of mobile technology after 3G". Technologies that are arguably comparable to LTE, such as mobile WiMax, have had a much narrower diffusion[6] and

[6] See, for instance, p. 3 in International Telecommunication Union (2013)

therefore taking them into consideration would not have a significant impact on the analysis carried out in this project.

Concerning the completeness of the dataset, there are several African countries which have not yet launched LTE services (i.e. the blanks in Figure 3). The analysis of coordination efforts in Africa at this stage may lead to partial results, given that the behavior of some African countries concerning the coordination of 4G licensing is yet unknown.

The analysis will therefore focus on the three regions where almost all (if not all) countries have already deployed 4G services: the Americas, Asia and the Pacific, and Europe.

3.2 Methodology

We construct the network structure based on a simple objective criterion: geographical borders. Each country is a vertex in the graph and those countries that share a geographical border have an edge joining them.

Figure 4 shows how the graph is constructed for the Americas region. In this instance, an additional edge is added linking French Guyana and France, given the obvious ties between mainland France and its overseas departments.

The Caribbean countries are not considered in the graph given that they are closely interrelated among themselves and many of them have not yet deployed 4G services. Only Puerto Rico is included, because it has stronger ties with the United States than with the rest of the Caribbean.

Following the same procedure we construct the graph for Europe (Figure 5).

We link Iceland with the closest Baltic countries (i.e. Denmark, Norway and Sweden).[7] We add an edge between Malta and the United Kingdom, given its recent historical ties and the fact that Malta is a member of the Commonwealth of Nations.[8]

Because of the Russian exclave Kaliningrad, several edges intersect in Figure 5.

[7]These countries have close links in the area of telecommunications. See for instance the joint reporting by the Swedish regulator of the telecommunication statistics in the Nordic-Baltic telecommunications market.

[8]For more information, see the Commonwealth of Nations website.

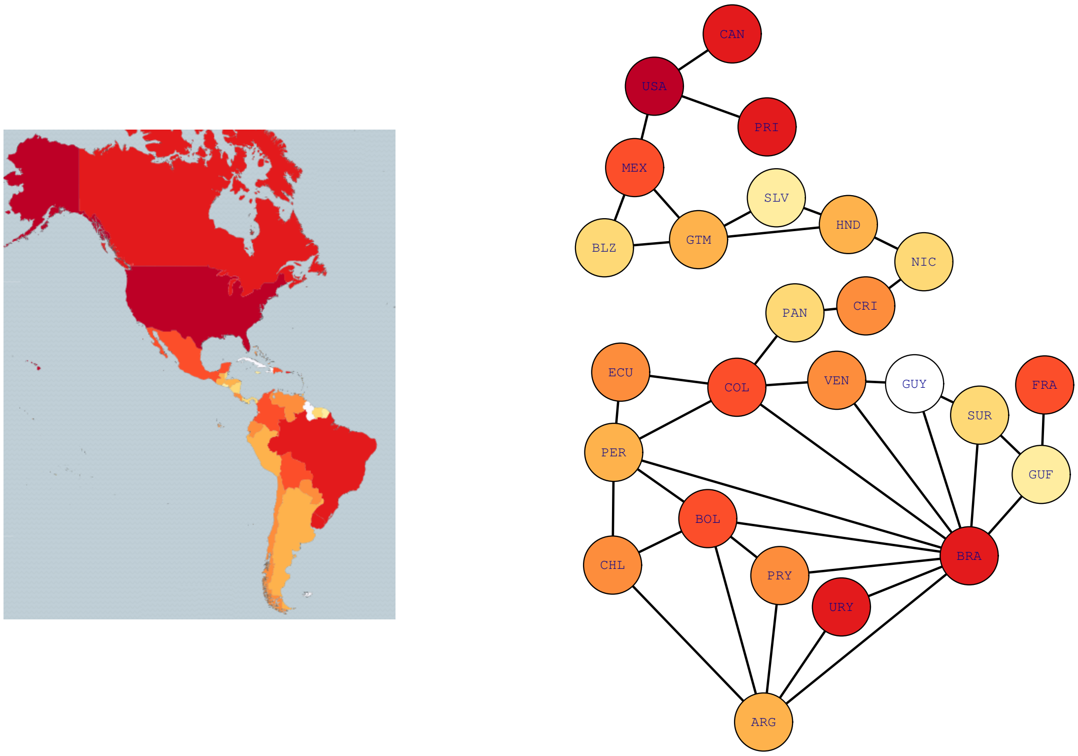

Figure 4: Construction of the graph representation of the Americas.

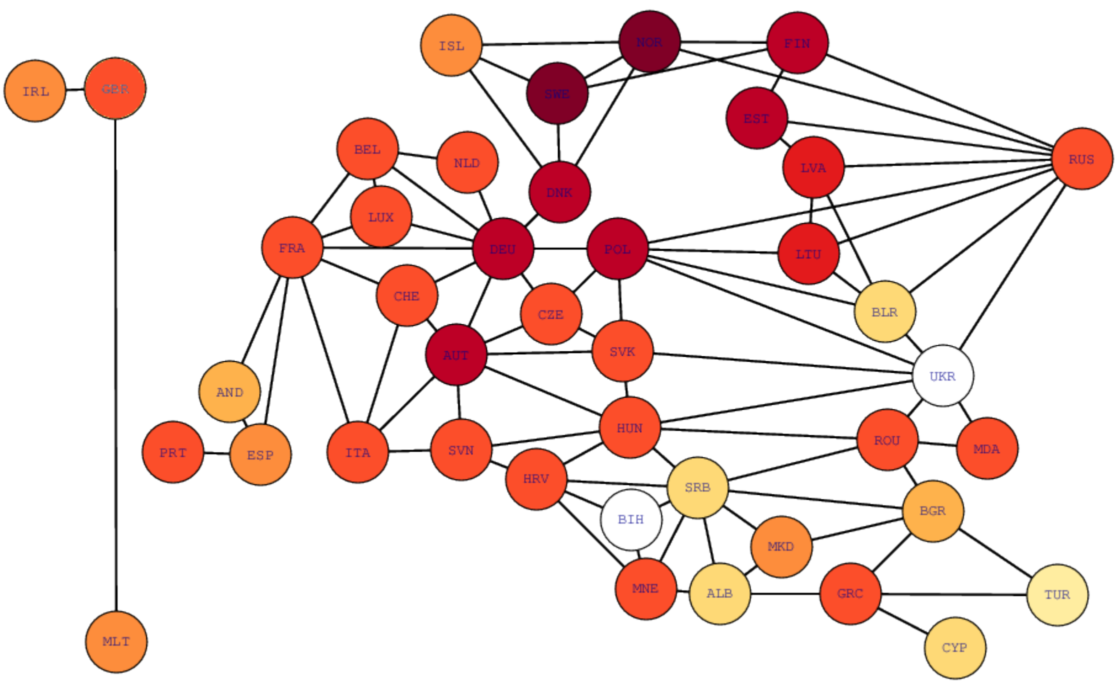

Figure 5: Graph representation of Europe.

We apply the same methodology to Asia and the Pacific (Figure 6). We do not include the small island states in the Pacific, because many of them do not have yet launched 4G and because their links would need to be determined using another methodology, given that they do not have land borders.

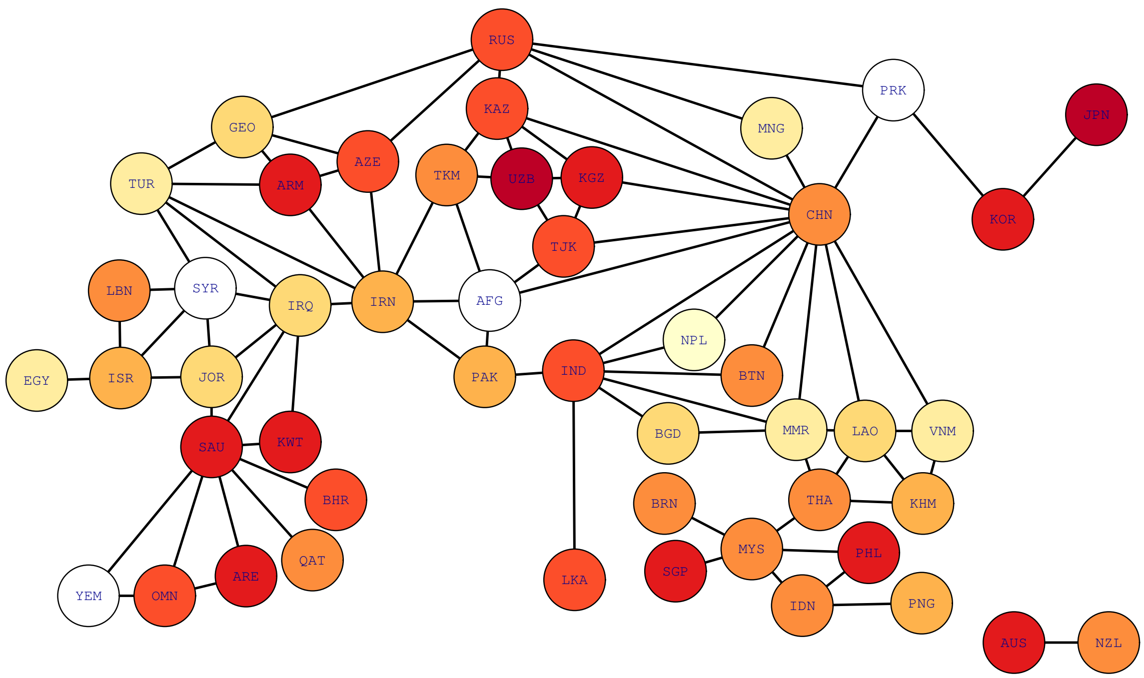

Figure 6: Graph representation of Asia and the Pacific.

Departing from these graphs, the proposed approach is to analyze the status of neighboring nodes (i.e. licensed/not licensed 4G) once a given country decides to license 4G.

For instance, Figure 6 shows that Viet Nam licensed 4G only after all neighboring nodes (Cambodia, China and Lao P.D.R) had already done so. On the contrary, Uzbekistan licensed 4G before its neighboring nodes (Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan).

By plotting the distribution of the percentage of nodes having already licensed 4G at the moment of each node's decision, we should obtain an indication of the existence or not of network effects in the decision-making process.

4 Results

4.1 The Americas

Figure 7 shows the histogram of the percentage of neighbors having licensed 4G prior or simultaneously to each country. A majority of countries in the region either licensed 4G after all their neighbors had already licensed the service or licensed the service when 20 per cent or less of their neighbors had done so.

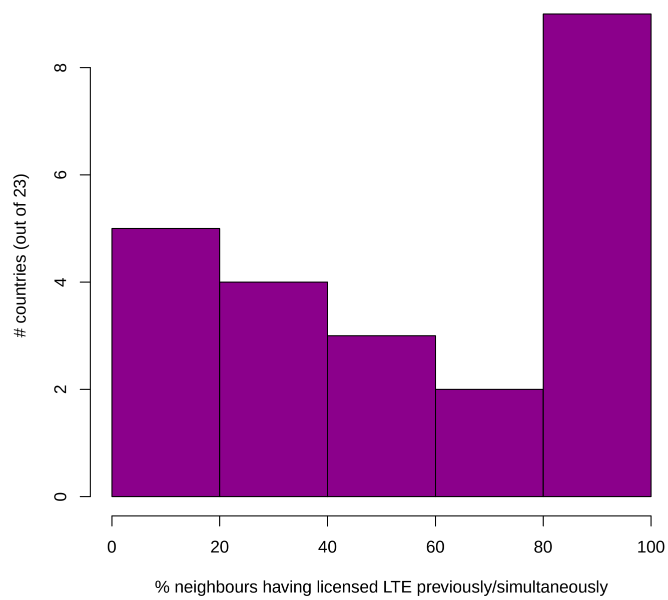

Figure 7: Histogram: LTE licensing in the Americas.

Figure 8 (left) shows the empirical cumulative distribution function (CDF) of 4G licensing as a function of the percentage of neighbors having licensed the service previously or simultaneously. The curve does not show much evidence of coordination effects. Indeed, we would expect a stronger s-shaped curve if coordination among countries had been strong (see Figure 2 for an example of a typical s-shaped curve with network effects).

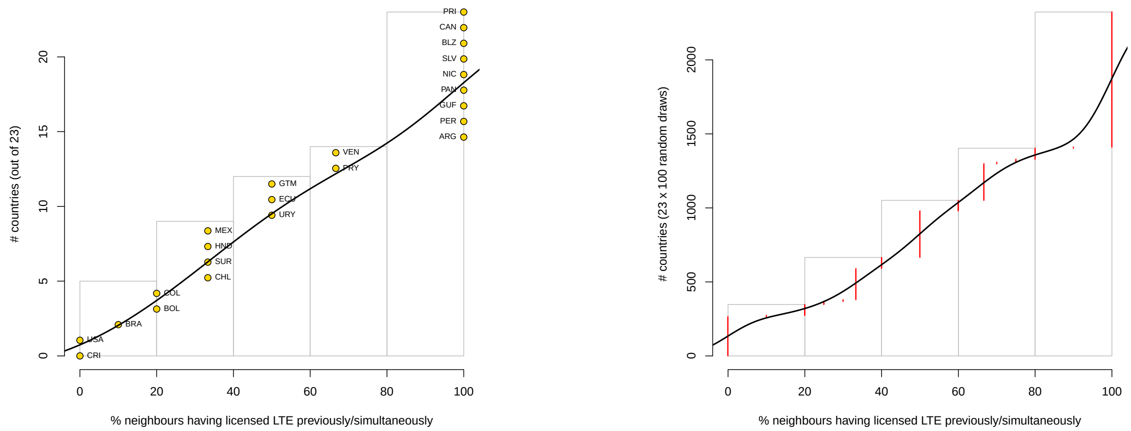

Figure 8: Cumulative histogram: LTE licensing in the Americas. Real data (left) and random generating model (right).

However, we need to consider the specific structure that we are imposing to the region before drawing a more robust conclusion. That is, the structure that we imposed to the graph (i.e. edges reflect geographical borders) makes that some distributions have higher probability than others.

For instance, if we had a graph forming a chain (i.e. each vertex having either one or two edges), then there would be only three states possible per vertex: (i) 0 per cent, (ii) 50 per cent or (iii) 100 per cent of the neighbors have licensed the service. That would induce a particular shape in the CDF.

In order to account for the effects of the graph structure, we run a simulation in which we randomly assign the year of licensing in each country. We repeat the process 100 times and plot the results (Figure 8, right). We see that the random CDF is relatively similar to that obtained with the real data.

Figure 9 plots the fit of the real and the random models in the same chart. The x-axis range spans a little beyond 100 per cent because they are fitted curves and do not reach the maximum (23 countries) at the exact 100 per cent.

We see that the real CDF shows a similar trend to the one obtained by random simulations. The oscillations in the random model fit should be attributed to the finer grain obtained when constructing the CDF with 2300 observations, rather than with only 23 as in the real dataset.

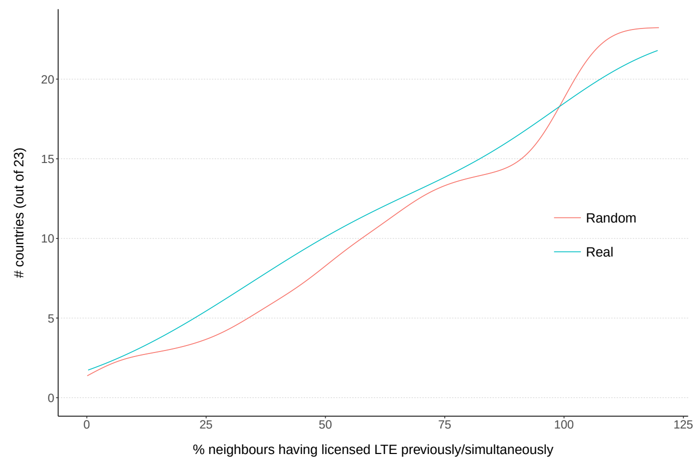

Figure 9: CDF model fits: LTE licensing in the Americas.

Based on these results, we conclude that our model does not reflect any significant evidence of coordination in 4G licensing in the Americas.

4.2 Europe

We apply the same analysis to Europe. In this case, we see that the CDF has a more pronounced s-shaped form than that produced by a random generating model (Figure 10).

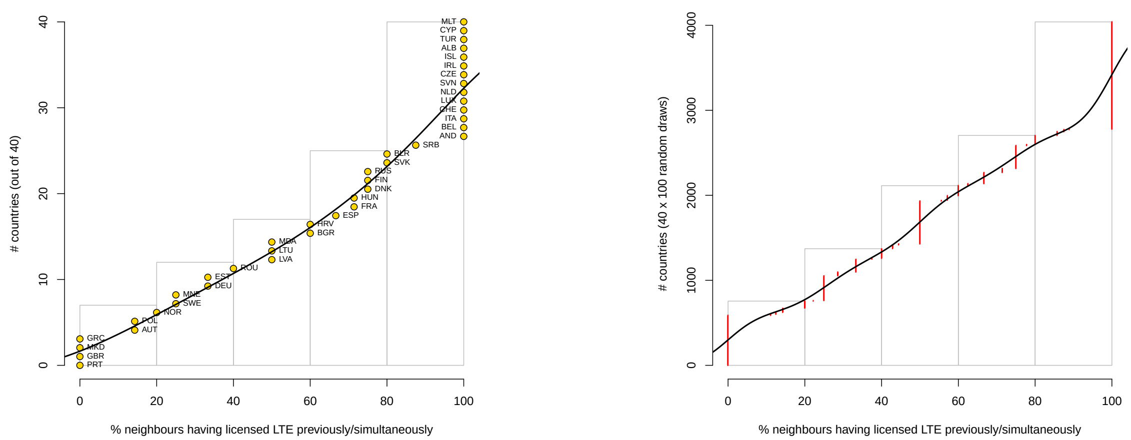

Figure 10: Cumulative histogram: LTE licensing in Europe. Real data (left) and random generating model (right).

Indeed, when plotting the two model fits together we see that in reality more countries licensed

4G simultaneously or after their neighbors than what would be expected if the choice were random (Figure 11). Analyzing more in detail Figure 5 we see that several connected countries decided to license 4G at the same year. It would seem as if they could be grouped into clusters.

For instance, several Baltic countries licensed 4G very early, in 2009 and 2010, when the majority of countries in Europe (and worldwide) had not yet deployed 4G. Likewise, most central- and Western-European countries licensed 4G in 2011.

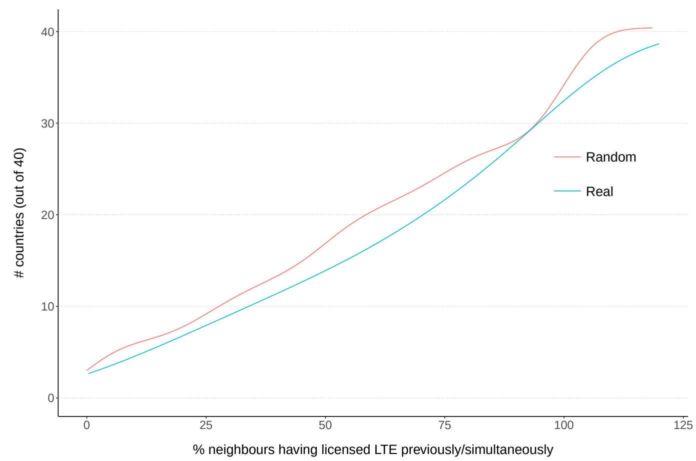

Figure 11: CDF model fits: LTE licensing in Europe.

These results suggest that there has been a coordination in 4G licensing in Europe. This coordination has not happened for the region as a whole, but rather occurred among groups of connected countries.

Previous analysis of 3G licensing in Europe also found evidence of coordination among countries (Cowhey et al., 2008). Our analysis would confirm that such a coordination has continued in 4G licences.

This is not a surprising finding, given the common regulatory framework for electronic communications that European Union countries share. Nevertheless, the network analysis suggests that the coordination has taken place between different sub-groups within and without the European Union, rather than among the whole EU as a block.

4.3 Asia and the Pacific

Lastly, we follow the same procedure for Asia and the Pacific. As in the case of the Americas, there is little evidence of coordination in 4G licensing according to our model (Figure 12).

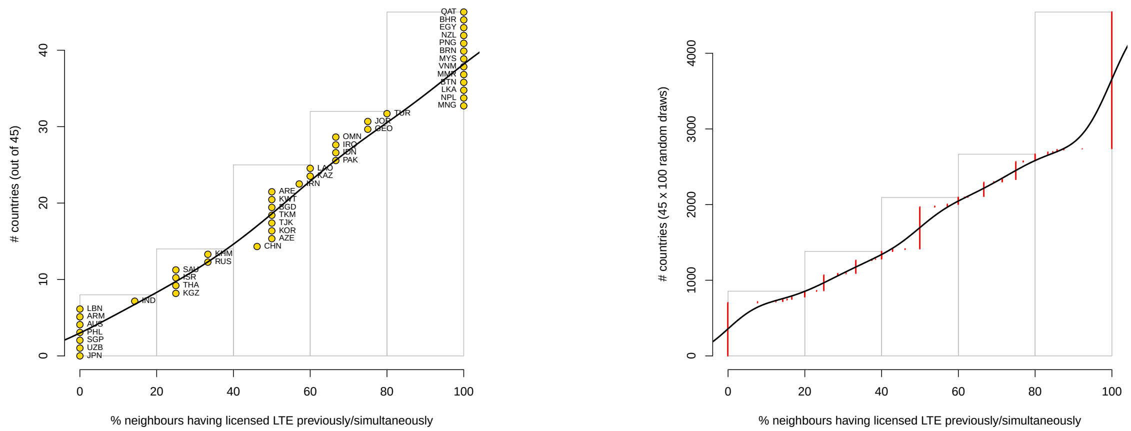

Figure 12: Cumulative histogram: LTE licensing in Asia and the Pacific. Real data (left) and random generating model (right).

The comparison of the empirical CDF and the random model confirms the absence of coordination effects under this network structure (Figure 13). Indeed, the random CDF has more of an s-shape than the real curve.

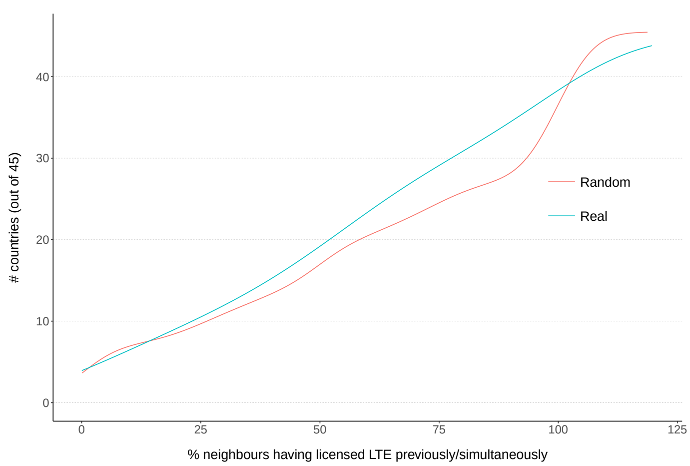

Figure 13: CDF model fits: LTE licensing in Asia and the Pacific.

A possible explanation for the lack of evidence of coordination may be the fact that we have analyzed in the same graph a geographical region – Asia and the Pacific – which is often divided into different sub-regions.

For instance, the International Telecommunication Union analyzes telecommunication developments in this geographical region by separating the countries into (i) Arab States (including some of the North African countries), (ii) Commonwealth of Independent States (CIS, ex USSR countries) and (iii) Asia and the Pacific (the remaining countries in the region).[9]

Such a sub-classification may better reflect the underlying links between countries when it comes to telecommunication policies. For example, trans-national operators tend to operate across these sub-regions, e.g. MTS and VimpelCom in the CIS,[10] Batelco and Zain in the Arab States.[11]

5 Conclusions

The analysis carried out in this project has found evidence of coordination in 4G licensing in Europe. Indeed, the graph analysis suggests that coordination has taken place between different sub-groups of countries in Europe, not just among European Union Member States.

On the other hand, we have found no evidence of coordination in 4G licensing in the Americas, nor in Asia and the Pacific.

The model proposed in this project has captured well the interdependencies among clusters of geographically neighboring countries, such as those that occur in Europe. However, it has not captured other types of dependencies which might be more relevant in other regions, such as the Americas and Asia and the Pacific.

Some of the possible causes for the lack of coordination found in these two regions are the following:

1. Network structure as coded by geographical borders may not reflect real regional links. Alternatives ways of constructing the graph could be based on:
   (a) Trade exchanges between countries.
   (b) The network defined by the transnational operators (i.e. drawing an edge between countries that share at least one operator).
2. We have just considered first order connections. A possible extension of this project would be to incorporate other network metrics that reflect the wider graph structure.
3. There are some minor refinements which might not change the results but that would be worth considering in any future work:

[9] For more details on the ITU regional classification, see ITU's website.

[10] For more information, see MTS' website and VimpelCom's website.

[11] For more information, see Batelco's website and Zain's website.

(a) Using natural years to sequence licensing may be too general an approach. Incorporating finer grain information, such as data on the month of licensing, may allow to improve accuracy. This may be particularly the case in the Americas, because it is the region with fewer countries and changes in a few of them could have an impact on the results.

(b) Percentage of neighbors having launched LTE might not be the right indicator. It is a purely relative measurement that could benefit from an absolute counterbalance. Otherwise, we are considering that a country that decides to license 4G at the same time as its only neighbor coordinates more than a country licensing 4G at the same time as four out of five neighbors.

It could be that the findings of this project are actually correct, i.e. there has been coordination in 4G licensing in Europe, not in the Americas nor in Asia and the Pacific. This is indeed a plausible result, given that Europe has shown to be the region with the highest degree of coordination in past mobile technology transitions.

However, more research would be needed to confirm the lack of coordination in other regions outside Europe. The suggestions highlighted in these conclusions could be taken as starting point for future research in this area.

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