Sundquist, Mårten; Markendahl, Jan

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A case study cost modelling of regulatory alternatives to mitigate the mobile network coverage and capacity problems in rural areas

Mårten Sundquist, Jan Markendahl
Wireless@KTH, Royal Institute of Technology, Electrum 229, SE-164 40 Kista, Sweden, email: msundqui@kth.se janmar@kth.se

Abstract
Despite a continued build-out of mobile networks, both mobile network coverage and capacity problems in rural areas are increasing. This counterintuitive situation is due to the exponential growth in mobile data usage, the long inter-base station site distance in rural areas and the increasing requirements on ubiquitous coverage not only for humans but also for the Internet of Things.

With today’s communication systems and business models, it is not commercially viable to solve the problems by the MNOs (Mobile Network Operators) alone. The paper aims instead of studying the different regulatory strategies available for NRAs (National Regulatory Agencies) to improve the situation.

The main focus and contribution of the paper is to make a cost modelling of the main regulatory solutions available to improve the coverage and capacity in rural areas. An overall cost benchmark is then made, where the relative cost for network operators, affected end-users and the public sector is displayed.
1 Introduction

1.1 Problem description

Mobile data usage has exploded during recent years, following the smart-phone ecosystem success and the major capacity increase in mobile networks. Undoubtedly, the dramatic increase of mobile data traffic will continue. Cisco (2014) predicts a Compound Annual Growth Rate (CAGR) of 61% during the next five years. Zander and Mähönen (2013), discuss a possible 1000-fold mobile data traffic increase during the ten year period up to 2020.

The success of mobile internet has significantly changed the end-user behavior and expectations on their service providers. End-users in rural areas today demand to be connected everywhere. Examples of end-user frustration of rural coverage includes the British prime minister missing vital calls (The Guardian, 2014) and also the Swedish Public Service Television coverage during 2015 of the poor mobile and fixed internet availability in rural areas (SVT, 2015).

Incomplete mobile coverage also affects the many devices that are increasingly used in the emerging Internet of Things (IoT) technologies. Vehicle tracking, eHealth services and rural industries such as forestry, wind power plants and farming are suffering.

Despite a continued build out of mobile networks in rural areas, the geographical coverage of Sweden is still only 83% for mobile voice and 48% for mobile broadband (>10Mb/s) (PTS, 2015). In Norway, mobile broadband covers 66% of the geographical area (NKOM 2014) and 78% in the UK (Ofcom, 2014). There are however some issues with these figures, as they are difficult to measure and Mobile Network Operators have a tendency to exaggerate the performance of their networks. The definition of 3G/LTE coverage is also not straightforward. Very high capacities (theoretically >50M bit/s) can only be achieved close the antenna and with few or no additional users in the cell. A view of how data throughput decreases with the distance to the base station is presented in Figure 1. In reality, the available capacity for the end-users in the outer parts of the cell is much smaller. When there are many users in large rural sites and/or heavy traffic is used, typically during peak hours or during vacation periods, congestion often occurs. The rural connectivity problems are therefore not only coverage related – but also capacity related.
In urban areas, where the distances between existing radio base station sites are short, the networks can relatively easily be upgraded for high capacity, using additional (high-frequency) spectrum and small-cells in a heterogeneous network. In rural areas, where inter-site distances are long, the situation is much more challenging.

The higher order modulation techniques enabling high capacity can only be achieved close to the base station. Decreasing inter-cell distances from 10 km to 1 km would require in the order of 100 times as many base stations – which is clearly not financially viable for the Mobile Network Operators (MNOs) today.

1.2 Paper objective and motivation

The digital agenda for Europe (European Commission 2013) clearly points out wireless broadband as key to economic growth, job creation and social inclusion in rural areas. Moreover, strong public intervention is considered mandatory to make this happen.

The market forces alone cannot fulfill the mobile connectivity needs and expectations of end-users and society. Regulatory aspects for rural areas have been taken into account for a long time, and the coverage provided by MNOs have increased significantly during the last years. However, the major market changes – with an explosion of traffic, changed end-user behavior and new requirements on human and IoT connectivity – clearly motivates this paper.

The aim of this paper is to identify and make a cost modelling benchmark of the main regulation options for National Regulatory Agencies (NRAs) in the EU to solve or mitigate the mobile coverage and capacity problems in rural areas. Depending of which strategy is selected by the NRAs, the cost
related to mobile connectivity improvements will be distributed differently between mobile network operators, the state support or by end-users.

1.3 Research Questions

The main research questions are:

- How are the network densification cost aspects affected by different regulatory options to increase coverage and capacity in rural areas?

- How is the cost divided between operator, the public sector and end-users in different regulatory setups?

2 Related work

There is a renewed interest in rural coverage solutions the recent years. Cost analysis of mobile networks infrastructure has been studied in Markendahl (2011). Ovando et al (2015) have investigated the feasibility and cost of providing high-speed LTE (30 Mbit/s) wireless services in rural areas in Spain.

Katsigianns and Smura (2015) has studied the general cost structure and most cost effective deployment strategies of mobile networks. Also, the speed of investments in rural areas is found to be mainly driven by regulator’s interventions.

Mobile Network Infrastructure sharing and its relation to overall cost has been studied by Frisanco et al (2008) and Mölleryd et al (2014). The main findings are the impact on the market model and co-operation relationships between different actors. Major savings of capital and operational expenditures were also identified and modeled.

The digital divide and the importance of broadband to the national economies is analysed by Prieger (2012). The paper finds that mobile internet has the ability to bridge many of the gaps present between the usage of fixed networks in urban and rural areas.

In Grajek and Röller (2010), a study of the relationship between telecom regulation and investment incentives was made, using data from 20 countries over 10 years. The analysis found that (fixed access) regulation negatively affected both industry and individual carrier investment.
3 Methodology

We review and discuss the regulatory activities and strategies used to increase mobile network coverage and capacity in rural areas. A have made a literature study of research papers and reports from MNOs, Infrastructure vendors, NRAs and competition authorities.

Interviews are made with the following parties:

- TKOM (The Norwegian telecom regulator)
  - Two participants: A senior adviser from the Service Markets Department and a manager from the spectrum department.
  - Skype meeting

- PTS (The Swedish Telecom regulator)
  - Three participants: Senior staff from the spectrum departments, from the technical department and from the department working with deployment aspects.
  - Face-to-face meeting

- Det Digitale Agder (A broadband deployment cooperation between municipalities and regions in southern Norway)
  - A main driver and decision maker of the above mentioned regional co-operation organisation
  - Telephone interview

- Ofcom (The UK telecom regulator)
  - A longtime director of Ofcom (now moved to another employer)
  - Telephone interview

In this paper, we will analyze regulations options that NRAs use to stimulate the build-out of high capacity mobile networks in rural areas. For the identified options a quantitative cost modelling benchmark is made to compare the different cost components involved for the different actors: network operators, end-users or the state/public.

4 Different regulatory alternatives to improve rural mobile connectivity

Being government controlled agencies, the NRAs always take rural aspects into consideration when licensing mobile spectrum and setting up the legal framework for the different market players. For more densely populated areas, the operators find it easy to make an attractive business case building out high capacity mobile broadband networks. In rural areas, however, where the traffic is low,
operators have difficulties of getting any return on investment – or even cover the operational cost of the site.

The regulatory bodies have a number of different alternatives available to stimulate or force additional build out in rural areas. The cases A-E described below will also appear in the quantitative analysis in the following chapter. In all cases, the capacity and coverage issues are solved by adding additional sites.

A. Reference case.

In the reference case, a Mobile Network Operator pays for the full Capital and Operational expenditures of the mobile network densification. If not financially motivated, the reasons for the build out can include:
- Fulfilling coverage license requirements. As licenses are regularly renewed, license requirements can be
- Marketing and increased end-user perception of the Mobile Network Operator
- Increasing service area for M2M/Internet of Things services

B. Regulatory incentive to MNO

In general, this case refers to the government subsidy of mobile broadband. Contrary to the situation for state funding of fiber access in rural areas, mobile networks in rural areas are seldom subsided.

One exception is the Swedish model when issuing the 800 MHz band. For one of the three 2x10 MHz licenses was attached a requirement to cover a number of “non-spots” in rural areas of Sweden. The overall license cost was decreased by 300 MSEK – which is to be used for the Capex part of the “non-spots” coverage. (PTS 2011). The modelling of this case (B) in the chapter below is based on the Swedish 800 MHz license subsidy model.

The recent agreement (UK Government 2015) between the UK Government and the MNOs seems to have a similar rationale. Ofcom and the UK government had discussed both an increase in coverage requirements and the cost of the mobile license renewal. Both these requirements were dropped as the operators committed to major investments to increase connectivity in rural areas.

C. End-user cost participation.

This case is based on a commonly used process in Norway, where end-users (typically local municipalities and regions) negotiate with the operators and agree to partly finance a number of sites in order to increase the coverage. An example is the agreement between Telenor and DDA¹ – a co-operation between different municipalities in Southern Norway (NRK 2011).

¹ Det Digitale Agder. http://www.dda.no
The rationale is that the region benefits so much from the increased mobile infrastructure not only in terms of economic development but also in social inclusion and citizen participation, that it agrees to co-fund the mobile network build out in the region.
The cost modelling below is based on the case of end-user participation implemented by DDA in Norway.

D. Mobile Network Sharing.
Mobile Network Infrastructure sharing is a well-known deployment model, which has been used during more than ten years. The economic potential of Mobile Network Sharing has been studied before (in for example Mölleryd et al, 2014) and is increasingly used by Mobile Network operators. In the calculation below, two operators are assumed to be sharing a (rural) network.
Before the telecom crises during the first years after 2000, mobile network sharing was rare. Operators were to a large extent competing using network quality and coverage. Different NRAs were also hesitant to allow network sharing due to the possible negative effects on competition. As mobile networks are increasingly commoditized and the network operators are struggling with decreasing margins and increased competition from Over-the-top (OTT) players, networks are increasingly shared. Recent examples include the (nation-wide) sharing between Telenor/Tele2 in Sweden (Tele2, 2009), PTC/Centertel in Poland (Deutsche Telekom, 2011) and Telenor/Telia in Denmark (Telenor 2011).
Although the telecom regulators are now more accepting network sharing, competition limitation concerns remains. In case there is no competitive advantage to increase coverage or improve coverage, why should Mobile Network Operators bother?

E. Society network.
This setup is a hypothetical extension of the previous case, as all operators build and run a combined radio network in rural areas.
In the calculations below is assumed that three different operators are sharing the network.

In real cases, a combination of the different cases may be used. In Sweden, for example, Telenor and Tele2 are doing network sharing and at the same time the (800MHz) frequencies are discounted as the combined network commits to cover a certain number of “non-spots”. A combination of the cases B and D apply therefore.

There are of course many other factors that can be taken into account when expanding mobile networks in rural areas. One important aspect is using lower frequencies. For European operators that have built 3G coverage on the 2 600 MHz and 1 800 MHz bands, obtaining frequencies (from the digital dividend) in the 800 MHz (or even 700 MHz) enables more cost efficient rural coverage.
5 Cost Modelling

5.1 Assumptions
In all cases the cost modelling below, a densification is made to improve coverage and capacity. In the reference case (A), the Mobile Network Operator is assumed to take the full cost of the densification. In the following cases, other actors are sharing the cost of the build out.

Both (Annualized) Capital Expenditures and yearly Operational expenditures are taken into account.

Relatively high cost is assumed for the passive equipment (feeders etc.) and the site itself. Rural base station sites typically needs civil work and use tall and expensive masts which also leads to high implementation costs.

Detailed assumptions are found in Appendix A.

5.2 Cost Modelling formula
The following model is used, the total yearly cost is assumed to be:

$$\text{Cost}_{\text{total}} = \text{Capex}_{\text{Active}} \cdot \text{Annuity}_a + \text{Capex}_{\text{Passive}} \cdot \text{Annuity}_p + \text{Opex} + \text{Cooperation}_{\text{planning/administration}}$$

The Cooperation term covers for the increased planning and administration cost when necessary when two parties jointly perform, allocate cost and (sometimes) negotiate network planning, operation and maintenance of (part of) a radio network.

5.3 Cost Modelling results
The calculations give the following results. Note that for all cases, the solution is to build additional base station sites. The graph below shows the cost per base station for the different actors involved.
Figure 2. The total cost per base station as a rural network is densified.

As seen in Figure 2, the different strategies and regulations related to rural areas lead to greatly varying cost structures. As discussed, the license subsidy case (B) and the End-user cost participation case (C) are applied in Sweden and Norway respectively already today. The structure however only applies to relatively few sites.

The Network Sharing case between two mobile operators (D) show that the cost (per operator) is greatly reduced. This case is, as discussed above, in commercial country-wide service in many countries in Europe. The more hypothetical Society network case (E) is an extension of the network sharing case to all mobile networks in a country (in this modelling example three networks). Due to the obvious potential risk of negative effects on the competition environment, the case (E) is not applied anywhere today.

Figure 3 shows the cost situation from the perspective of an individual MNO only. As can be seen it is mainly the Capital expenditures that are reduced compared to the reference case. Note that for urban sites, using small towers and structures, where power and transmission is often already available and the implementation cost is low, the relationship between Opex and Capex are more evenly distributed.
Conclusion and discussion

The paper aims to highlight and explain the problem areas related to coverage and capacity limitations in rural areas. The techno-economic study and quantitative analysis aims to be of theoretical and academic interest, but also of value to NRAs and industrial actors. As the mobile broadband services become more ubiquitous and the society becomes more connected, the lack of mobile coverage and capacity will be an increasing problem without proper actions. Fortunately there are a number of different options available – with different costs associated for different actors and different regulatory efforts needed to be done.

The different regulatory related aspects have major impacts on the cost structure and the overall cost of implementing improved mobile connectivity as displayed in the Figures 2 and 3 above. Seen from an individual operator, the build out cost can be decreased by any or a combination of the following factors:

- State subsidy of the license
- End user cost participation
- Sharing cost with other mobile network operators

Figure 3. MNO Cost per base station as a rural network is densified.

6 Conclusion and discussion

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The different regulatory related aspects have major impacts on the cost structure and the overall cost of implementing improved mobile connectivity as displayed in the Figures 2 and 3 above. Seen from an individual operator, the build out cost can be decreased by any or a combination of the following factors:

- State subsidy of the license
- End user cost participation
- Sharing cost with other mobile network operators
There is a rationale in each of the three alternatives. Considering social inclusion, rural economic development, cultural integrity and emergency communication, it is not unreasonable that the state in some way subsidizes the cost of building out rural connectivity.

Seen from the end-users perspective, it is also reasonable that the end-users (via local tax funded municipalities), or even rural industries like farming or forestry, contribute in the continued build-out in rural areas. The business case for the MNO is so weak, and the value of increased mobile coverage and capacity so great, that end-users should be allowed to co-finance.

Network sharing is already underway in many countries in Europe, and great savings are identified for both the operational costs and capital expenditures of the MNOs. Considering the risks associated with decreased competitive advantage of increased coverage and superior network quality, the number of networks should however not be decreased to one (society network).

Whoever pays for the mobile connectivity improvements, there are large and growing needs. Enabling excellent mobile broadband connectivity in rural areas increase the productivity of rural industries and social services. It also increases the quality of life, society inclusion and environmental aspects, as a larger portion of the population can work from home and have access to media services, e-Health applications and remote business services.
Appendix A: Calculation assumptions

The following assumptions have been made in the calculations:

- Basic assumptions include (all assumptions can be found in appendix one):
  - Site cost (incl. tower, roads, implementation): 400 000€
  - Active equipment (incl. Base station): 10 000€
  - Opex per year: 12 000€
  - Cost of Capital: 8%
  - Depreciation Passive equipment (towers etc): 20 years
  - Depreciation active equipment: 10 years

- In the network sharing case, an additional co-operation/administration cost is assumed – 1 500€ per site

- In case of sharing implementation cost with NRAs or local actors, there is assumed to be an additional one-time co-operation/planning cost of 3 000€.

References


