Rural ICT Testbed - #fulltäckning

#FULLTÄCKNING

RURAL ICT TEST BED

Value chains, operator sharing models, and regulatory aspects

VINNOVA

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Contributors

Johanna Lindberg, Luleå University of Technology

Elmar Trojer, Ericsson Research

Johan Jobér, Netmore

Jaap van de Beek, Luleå University of Technology

Jonas Tiger, IT Norrbotten

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1 INTRODUCTION

Providing (close to) full surface coverage has become an important requirement for current and future mobile communication systems, especially with the advent of 5G, promising superior connectivity anywhere and anytime. Different industries and organizations are investigating the possibility to run critical communication services over a global wide-area communications network that can deliver reliable and predictable performance over a large distributed or contiguous geographical area. The automotive industry, the transport sector, logistics sector, electricity companies, forestry, mining, railway companies, health & care services, public safety, and national security are some examples that require distributed and reliable communication to enable or improve value creation and efficiency in operation [1] [2]. Even in countries with highly developed cellular infrastructure there is typically a notable gap between population coverage and area coverage. To exemplify, in Sweden the area coverage is currently in the order of 90% while 99% of the population have access to adequate broadband services[1] in the area where they live [3].

Key aspects of lacking mobile broadband connectivity in sub-rural and rural areas are e.g. hindrance of digital inclusion of people; inhibiting local businesses to grow and thereby limiting the gross domestic product of countries; reduced quality of education and health care; difficulties to attract foreign direct investment, etc. According to [4] 3.5 billion unique mobile subscribers are globally using mobile networks to access the Internet, while 3.8 billion people are still offline either because of lacking coverage (coverage gap, 1.2 billion people) or they have coverage but are lacking means to connect (usage gap, 2.6 billion people).

The gaps mentioned above result from the techno-economic situation and local regulatory landscape that mobile network operators (MNO) face. Providing rural coverage is typically twice as expensive with a potential revenue as low as one tenth compared to urban deployments [4].

The UN agenda 2030 for sustainable development [5], mentions 17 global goals whose fulfilment directly or indirectly relates to ICT infrastructure providing wide-area coverage. These goals target people wellbeing, good health, equal education, decent work and economic growth, reducing inequalities, sustainable cities and communities, climate action, which of course is good. But, the indicators are not always favouring the rural areas where few people live far away from each other. If you have an indicator that favours as many people as possible getting access to the internet, the few who live far away will never get the internet. Since the percentage increase the indicator will show, will not economically justify an expansion of mobile coverage in these areas. In this case it would be more interesting to measure surface coverage, then you will include the rural areas where agriculture, forestry and tourism are big industries. The global goals 4.4, 5.B, 9.C and 17.8 have indicators aimed at the number of people who have access to technology in one way or another. These goals could also benefit from having surface coverage as an indicator, to include the rural areas. We are not suggesting that the indicators should be replaced, but supplement them, as we know that there are many more people in Sweden not using the internet, than people without access to digital infrastructure as mobile coverage. An effect of this is shown in the Swedish translation of the goal 4.3 Equal Access to Affordable Technical, Vocational and Higher Education where the words “affordable technical” is dropped. Perhaps they thought that this is not an issues in Sweden, as people can afford technology and the municipalities support the students with computers. But is impossible for an individual to pay for broadband connection.

In this report we examine some promising solutions to overcome this issue. The need for coverage in combination with a clear value proposition ask for new approaches, not only technological but more importantly in the network-operational regulatory domains. In a previous report [] we have been describing technological solutions and approaches. This report addresses other aspects and actions that are needed. We identify three dimensions where new regulatory and network-operational structures can make a large difference for connectivity in rural regions. In Section 2 we address ***new ways to use the radio spectrum***. Section 3 discusses ***novel models to operate networks***, by sharing of existing infrastructure, as well as the establishment of new non-public network ownership and deployment models. Section 4 addresses the value and need of ***national roaming*** and Section 5 summarizes this report.

[1] Defined as 30 Mbps in downlink and 256 kbps in uplink

2 SPECTRUM LAYERING AND SHARING

Availability of spectrum is a key asset for building coverage, regardless of whether it is used by *Mobile Network Operators* (MNOs) for rural *mobile broadband* (MBB) coverage, or by DSOs operating on national or global level. Existing structures for using the radio spectrum have been and are hampering the development of rural connectivity.

While many frequency bands already are assigned for cellular services, with the recent introduction of 5G, new frequency bands are made available in high-bands to enable high capacity and low latency for massive and critical *machine type communication* (MTC) services but also in mid and low-band to enable good MBB coverage, see *Figure 1*. In general, proper *combination* of new low bands below 1 GHz with good range but limited capacity with legacy-bands or new mid-bands to add capacity by means of *dual connectivity* (DC) or *carrier aggregation* (CA) gives a good trade-off in terms of coverage versus capacity.

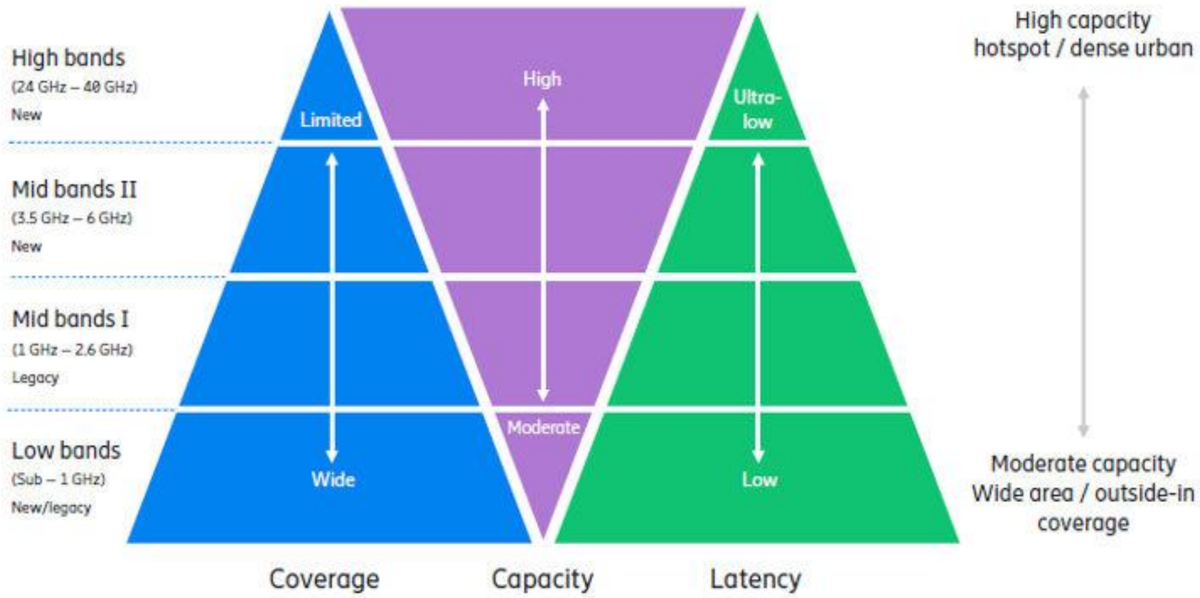

Figure 1: Spectrum trade-off [14]

Access to spectrum is typically acquired by a winning bid in a national spectrum auction by an MNO or DSO that decide based on business cases which areas to cover. Historically, most spectrum used for cellular services has been made available by nationwide licenses. Unfortunately, this does not guarantee that the spectrum is actually used everywhere by operators, in particular in rural regions. Regulators assess this problem in a number of ways.

COVERAGE REQUIREMENTS IN NATION-WIDE LICENSES

As a first means to force spectrum to be used, local regulators can put incentives for MNOs to build rural coverage by putting additional requirement on the band. A part of the cost for the band can e.g. be mandated to be used to extend coverage into underserved areas. Such demands are generally used on low frequency bands.

As an example, in Sweden, a block of 2×10 MHz for *frequency-division duplex* (FDD) operation in band B28 (700 MHz) was constrained with coverage build-out rules to improve voice and data coverage in rural areas. The regulator established a map of underserved areas of different priorities, i.e. colors in *Figure 3*, arguably of strategic importance[2]. The winning MNO for that block is required to gradually cover the prioritized areas over time (25% per year). Red areas come first lacking both outdoor voice and data coverage (10 Mbit/s) followed by blue areas providing outdoor voice coverage but lack data coverage. Those areas should be converted to green areas that possess voice

[2] *The areas included in the map were chosen based on their lack of coverage according to operator-provided coverage maps, and based on their proximity to roads, households and cottages – important tourist areas or businesses could therefore be left outside. A 20 km² limit was adopted and any smaller area has been ignored.*

and data indoor coverage. Also, parts of the 450 MHz band enabling full-coverage are associated with coverage and data-service requirements (e.g. 80% data coverage per district with at least 5 Mbit/s in downlink and 128 kbit/s in uplink [15]). It is worth noting that for other blocks in the same band, there's no coverage demand at all, although it is safe to say that where the operators have 800/900 MHz infrastructure, that will be expanded with 700 MHz as well but then foremost for capacity reasons. A small coverage gain will be seen anyway thanks to the 700 MHz lower free space attenuation.

Another way of putting coverage requirements can be seen in the 2100 MHz 3G license auction back in the early 2000's, which was in the "Beauty Contest" form. In this case, operators' biddings were made in the form of number of people covered. The operator then must ensure to meet his own bid. In this specific case, all operators maximised their bids, which in the end resulted in ~99% people covered, but very little area coverage.

Also, in some cases, in Sweden e.g. in the 900 MHz band, there's a demand for specific road coverage, valid for all operators.

In mid bands such as the 2,6 GHz 4G band and probably also in the upcoming 3,4-3,7 GHz 5G-band, a coverage demand is usually non-existent, or very limited and thereby fairly easy to achieve. Usually, these bands are handed out through a pure auction bidding process. Together with the very limited area coverage obtained from an individual site in these bands, in geographical terms usage will be very low and mostly restricted to cities. In long term, perhaps there'll be mid band coverage also on main roads and small villages (200-1000 HH) but most probably not within more rural areas through these Nation-wide licenses. Therefore, the idea of sharing/leasing of spectrum becomes interesting within these bands.

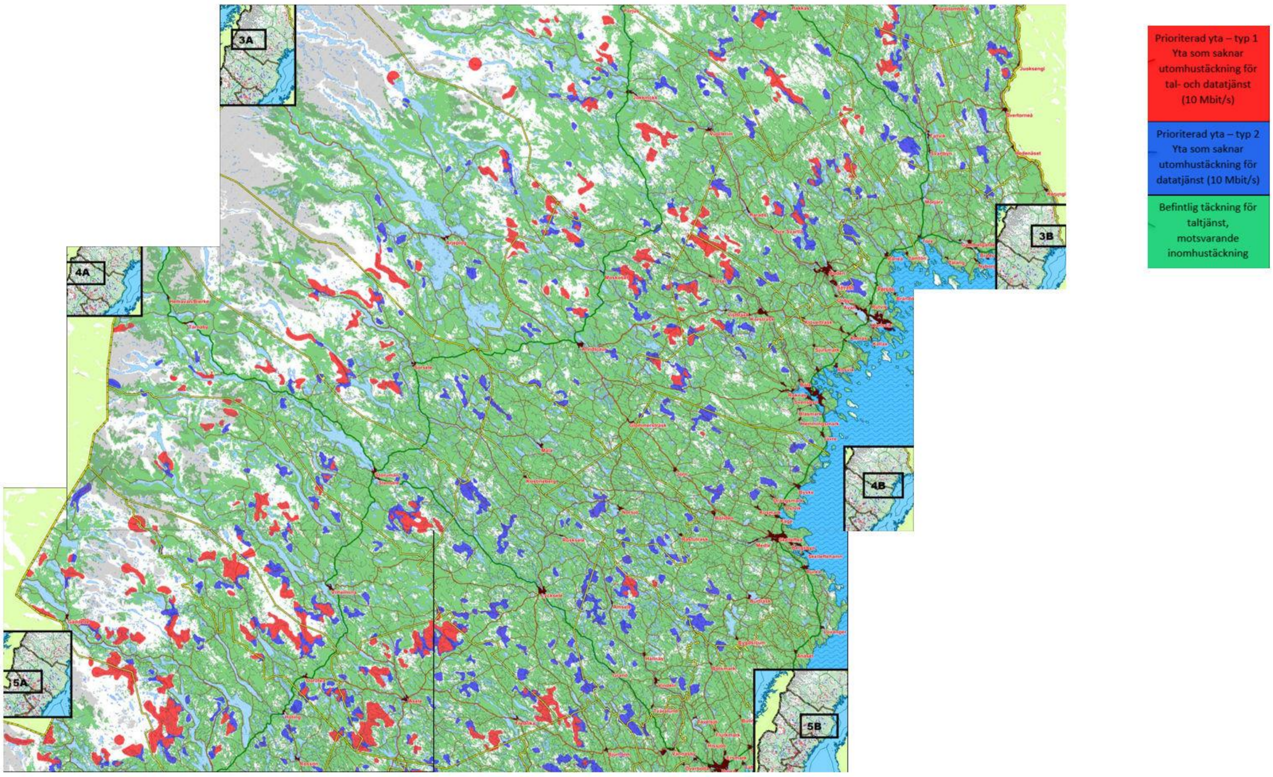

Figure 4: Prioritized area-coverage map for Northern Sweden [16]

SHARING AND LEASING OF SPECTRUM LICENSES

Another approach to economically increase coverage are regulatory introduction of license sharing or leasing models. The common model of operators gaining access to licensed spectrum for exclusive national and multi-year usage has recently been complemented with new models for license leasing/sharing – *licensed shared access* (LSA) and *spectrum access system* (SAS) [14]. In case a piece of spectrum is not used at a given time and place by its incumbent, other players can temporarily rent it for a reasonable price or just start to use it, as is common practice in unlicensed bands.

In order for unused licensed spectrum to be used in the rural, the notion of "local licenses" must be developed as a complement to nation-wide licenses. The most favorable definition of many local areas is being land ownership/real estate-based as these areas are already established in land registers and prevent hoarding of, and speculation in, spectrum assets. Such a concept should be evaluated in more detail and also with respect to particular regions *cases, especially in the north Sweden, where some of these real estates can be huge and scattered (not homogenous).*

Licensed shared access

In Europe, beside classical national licenses, the new concept of "local license" to enable industrial and rural applications is adopted (e.g. Germany and Sweden in 3.7-3.8 GHz). In many countries, the spectrum auction process of the 3.5 GHz band (3.4-3.8 GHz) are in preparation with LSA-based solutions in mind.

An evolved *license-shared access* (LSA) architecture as described in the ETSI standard *TS 103 235* is illustrated in *Figure 2*. It comprises a repository, a database, that contains the up-to-date usage of spectrum over space, at any time. These details of spectrum usage over space and time contain the usage a priori required by an incumbent, but also the use as granted to LSA licensees (like MNOs) under the supervision of the *national regulation agency* (NRA) [17]. Based on this utilization information, MNOs can gain access to and release spectrum, via eLSA controllers for exclusive use in m*obile/fixed communication networks* (MFCNs) ***for a given duration in a local area***.

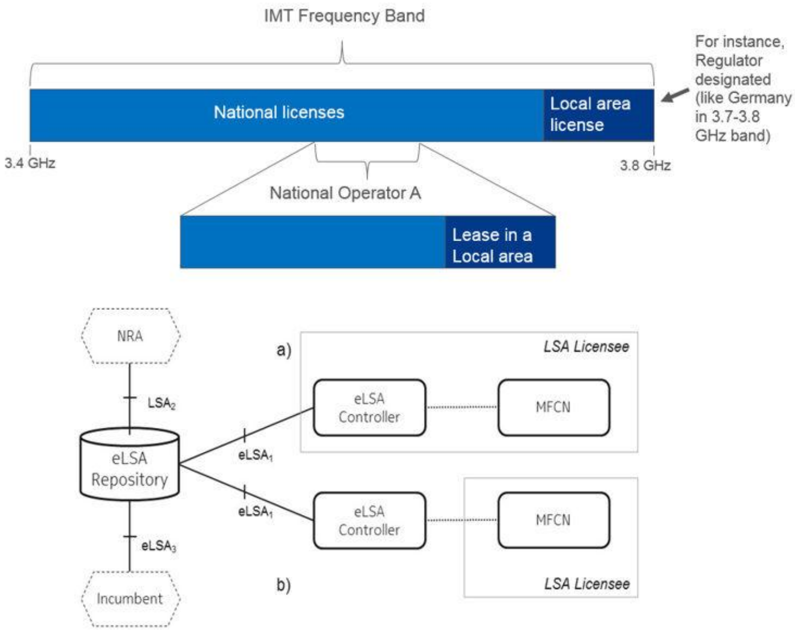

Figure 3: Licensed spectrum access reference architecture [14].

Spectrum access system

In the US, the *Federal Communications Commission* (the regulatory body FCC) promotes a similar but more general solution for the usage of the *citizens broadband radio service* (CBRS) band at 3.5 GHz [17].

Figure 4 illustrates the US concept. It differs from the European approach in that the incumbent spectrum users do not have to provide a priori information of their spectrum use. SAS provides dynamic coordination_of spectrum channel assignment. Devices that wish to use spectrum, request a local, temporary license via SAS. Instead, an environmental sensing capability (ESC) is used to fill utilization data in FCC database.

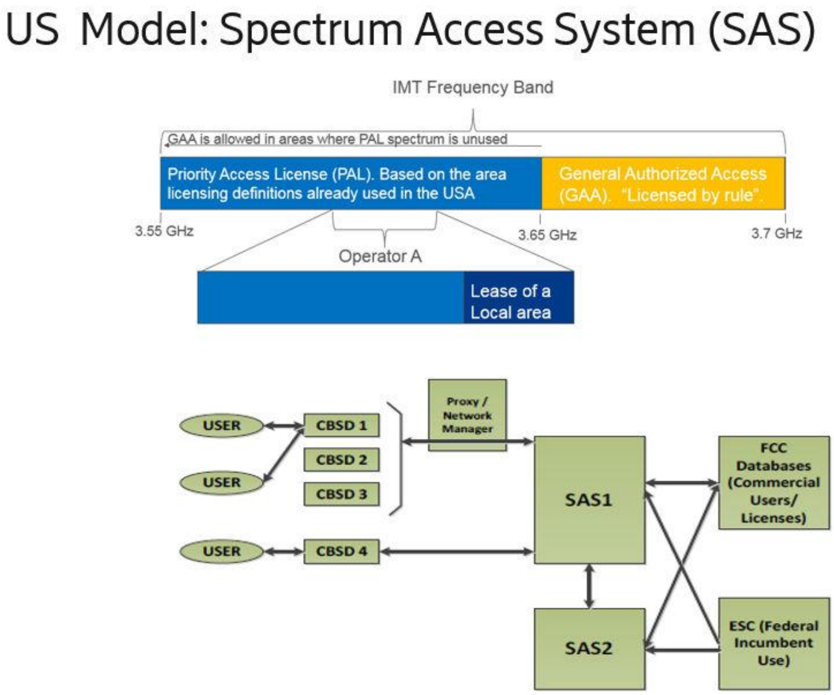

Figure 4: Spectrum access systems

Rural solutions

In summary, today, in rural regions spectrum is often not used. ***Those who have the means to use spectrum don't want to, and those who want to don't have the means***. National operators that have acquired nation-wide licenses typically choose not to deploy a network in the rural unless strongly promoted through benefits/discounts. Other potential local users, who do see potential business value of the spectrum are then locked out and cellular coverage for residents, visitors and industries remains absent.

Availability of new ***local licensing structures*** is therefore crucial. Thresholds to acquire and use spectrum by new local actors must be lowered. In this chapter we have outlined some developments and approaches that may make this happen in the future. The approaches described above all apply to spectrum that is principally licensed to nation-wide operators, but exclusivity is in various ways conditioned. Even fully unlicensed bands could provide significant advantages in the rural.

3 OPERATOR SCENARIOS, NON-PUBLIC NETWORKS AND NETWORK EQUIPMENT SHARING

The upcoming generation of cellular systems will have many more applications than previous. A much more diverse landscape of network operation models will emerge. The single nationwide operator model that provides all services will soon be complemented and enriched with new models.

Providing services that require extended coverage can be achieved by either integrating into existing MNO infrastructure or by establishing ***isolated non-public networks (NPNs)***, next to the traditional ***public land-mobile networks*** **(PLMNs)**

This choice depends on the key requirements of the particular ***vertical***, one of them being if coverage is living/visitors critical, business-critical, or mission-critical for the service, respectively. Some business segmentations for a few example verticals are depicted in *Figure 5* making clear that there is no one-size fits all solution.

A public safety or defence network typically needs to be realized as an NPN with mission-critical requirements on full national areal coverage, security, stability, and autonomy. The large initial cost for such an isolated deployment would be justified by having an autonomous, robust, and secure system. Other more cost constrained verticals can rely on a DSO integrating with existing MNO infrastructure providing global, but locally limited coverage.

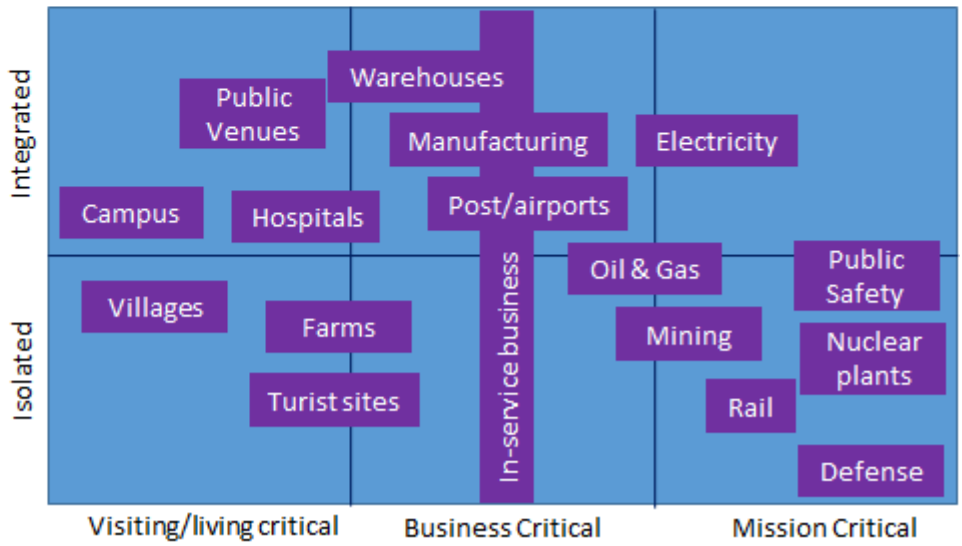

Figure 5: Key requirements on coverage and acceptability for integrating with existing public infrastructure are different for different verticals.

Depending on the degree of MNO asset re-used, different sharing levels of networking entities are possible: Network slicing (on the *radio access network* (RAN) and/or on the core network levels), *access point name* (APN)-based MNO sharing, re-using multiple MNO networks by establishing a *private virtualized network operator* (PVNO) or national roaming are some extreme cases where the vertical has no or very limited own equipment on the premises.

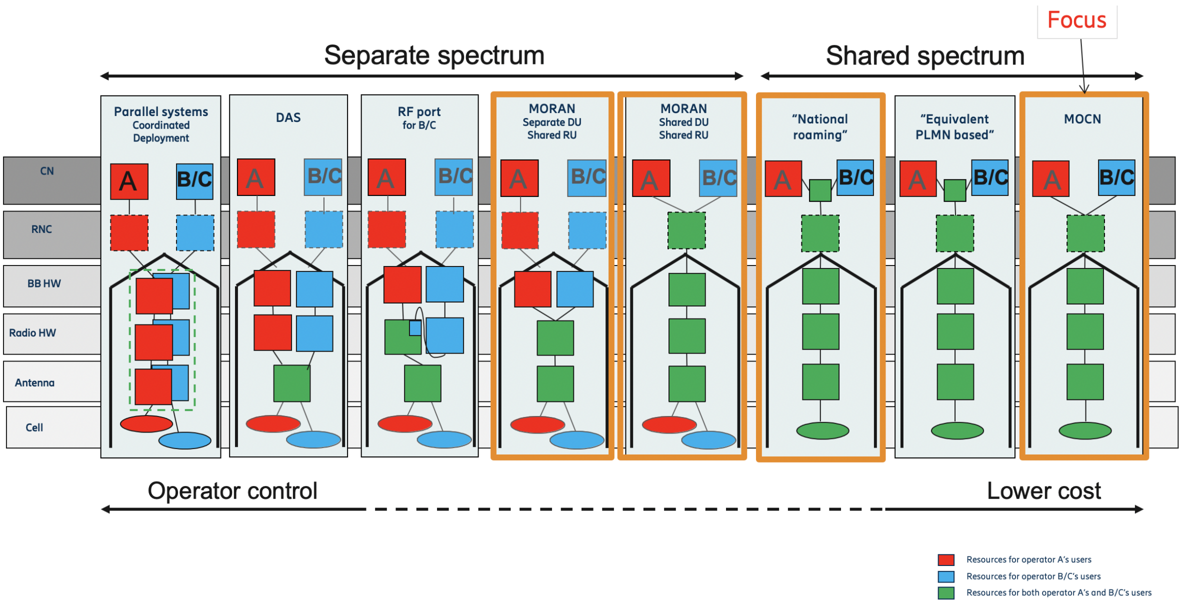

Figure 6: Various levels of infrastructure sharing

Figure 6 illustrates various ways to share the infrastructure, both the RAN and the CN, among operators. Deployments to the left have very little shared functionality, while operation deployments to the right have a high level of infrastructure sharing. Likely the rightmost scenarios will be beneficial for providing coverage in rural regions.

The sharing level increases with *multi-operator RAN* (MORAN) and *multi-operator core-network* (MOCN) deployments where the vertical owns a private core network but shares the RAN, either on the same spectrum on different network IDs (private PLMN IDs) [13].

Figure 7 illustrates a few of the scenarios of *Figure 6* in which two operators share network infrastructure, one operator being a traditional MNO, and the other an isolated, locally deployed non-private network, see [21]

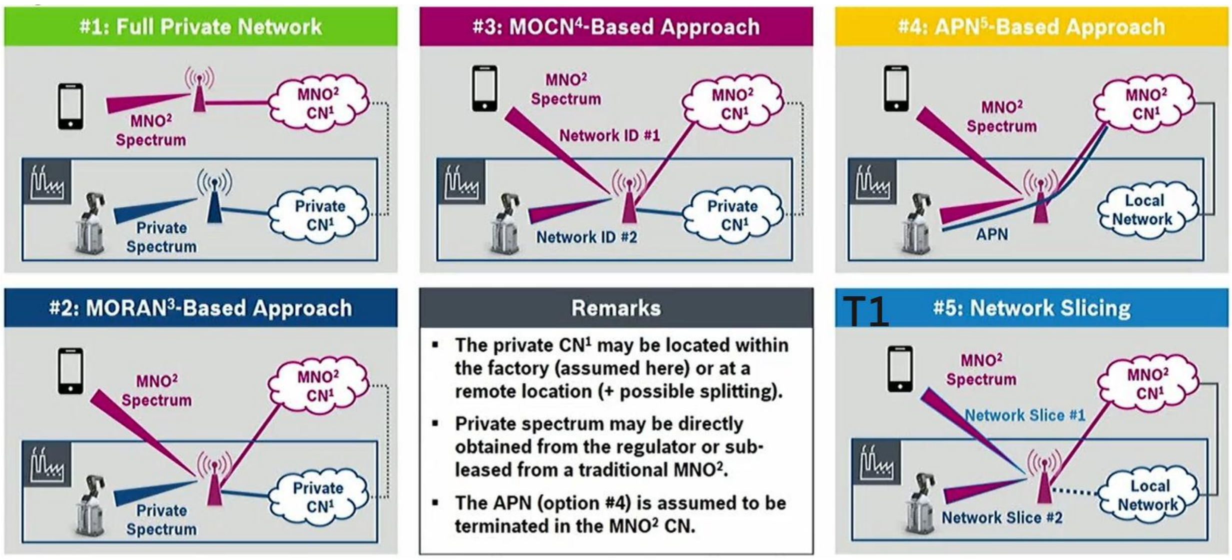

Figure 7: Network sharing options, from [21]

Isolated Network:

Isolated networks are mostly of interest in today's discussions in applications related to industries and business and in the context of the *Internet-of-Things* (IoT). NPNs can be desirable because there are high industry requirements on quality-of-service, on security, that isolation from other networks is required or industrial accountability. It appears that many of the industrial scenarios deal with a variety of use cases and different configurations of a private network are suitable in different situations. However, much of the insights can more or less immediately be projected on local hotspots in the rural.

Characteristics of these networks, illustrated in more detail in *Figure 8*, are:

- All NPN functionalities are on-premises
- NPN is totally separate from the public network
- There is a dedicated NPN ID
- The only connection to the PLMN (optional) services is via firewall and with a roaming agreement with PLMN(s)
- Dual subscription is possible
- Industry is the sole and exclusive responsibility for operation

Not all industries are able to operate 3GPP, i.e. some connection to a PLMN can be required, e.g. some level of support. Not all industries want to deploy a full-fledged 3GPP network to cover all functionalities and *use cases* Example: Mining company could have an isolated NPN for the mine but needs roaming, e.g. coverage for transport.

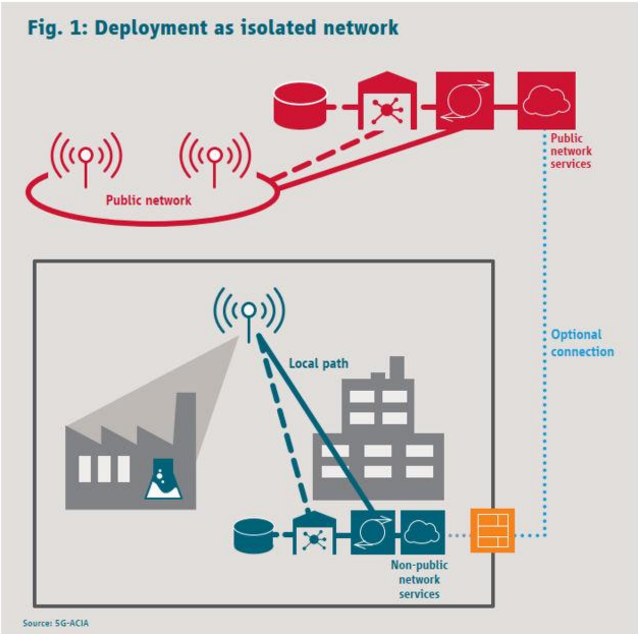

Figure 8: Deployment as isolated network

Shared RAN

A second deployment is referred to as the "shared RAN". Characteristics of these networks, illustrated in more detail in *Figure 9* are:

- *The NPN is based on 3GPP with its own NPN ID and it shares the RAN with the PLMN*
- *All other network functions remain segregated*
- *All data flows related to the NPN are local*
- *RAN sharing solutions are "MORAN" and "MOCN"*
    - ***MOCN** (Multi-Operator CN) most discussed. RAN is shared, i.e. two or more entities sharing eNodeB and spectrum*
    - ***MORAN** (Multi-Operator RAN) less popular. Two or more entities share an eNodeB, but having their own non-shared spectrum (e.g., own DU and antenna)*

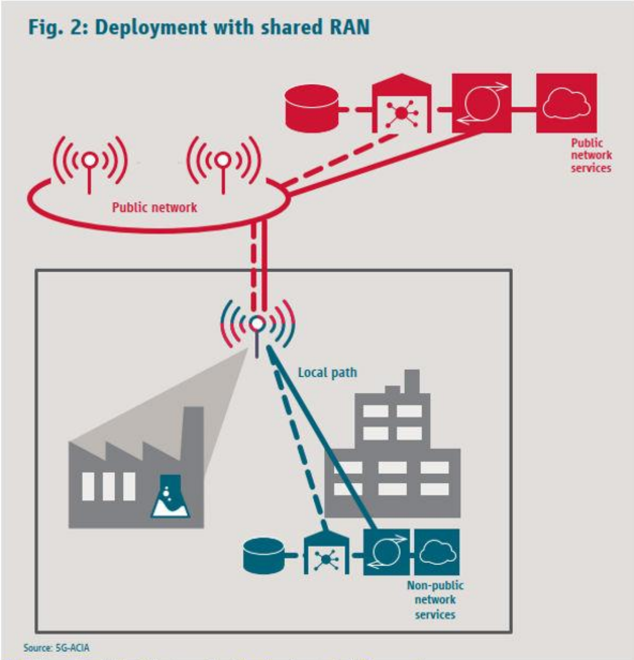

Figure 9: Deployment with standard RAN

SHARED RAN AND SHARED CONTROL PLANE

A third deployment is similar to the previous one but ***with a shared control plane.*** Characteristics of these networks, illustrated in more detail in *Figure 10*, are:

- *RAN and CP is shared with the PLMN (CP in PLMN-site)*
- ***Network control plane, e.g. authentication, hosted by the PLMN (i.e. the security system of the operator/PLMN is used)***
- *All data flows related to the NPN are local*
- *Public network traffic is transferred to the public network*
- *Segregation realized via APN, slicing IDs, etc.*
- *NPN is hosted by the PLMN, and* ***NPN devices are PLMN subscribers***
- *It allows NPN devices to connect directly to the PLMN, e.g. roaming, it allows NPN devices to connect to NPN services via the PLMN when outside coverage.*

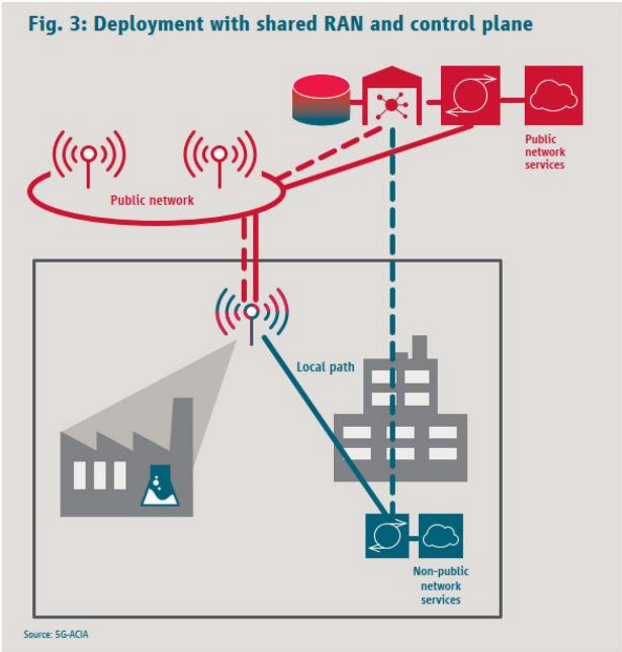

Figure 10: Deployment with shared RAN and control plane

NPN DEPLOYED IN THE PLMN

Finally, a fourth deployment involves a virtualization of the NPN. *Figure 11* illustrates this deployment in more detail. Characteristics of these networks are

- *Both PLMN and **NPN traffic are off-premises**, but treated differently*
- *realized through virtualization of network functions, and Access Point Name (APN) / slicing IDs, etc.*
- ***NPN devices are PLMN subscribers***
- *all data is routed via the PLMN, access to public services or roaming can be easily implemented in the agreement between the NPN and the PLMN*

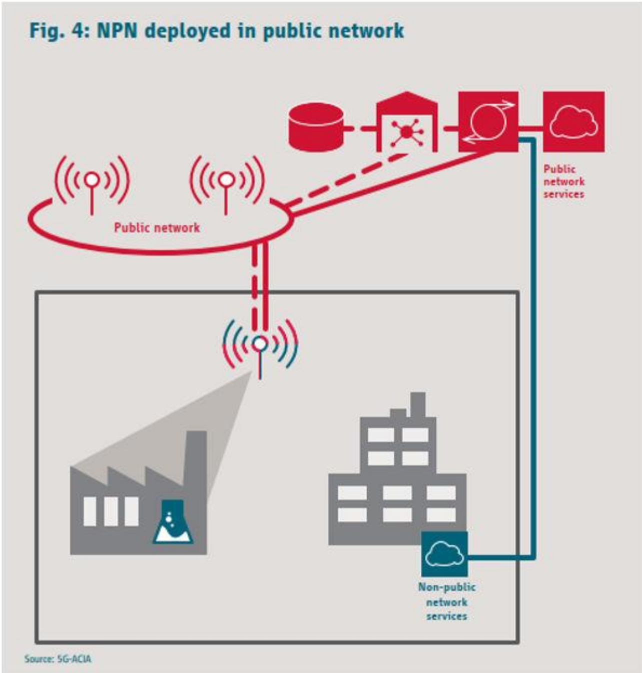

Figure 11: NPN deployed in public network

RURAL SOLUTIONS

For rural regions, we have considered in our previous report [20] a critical solution of the rural hotspot. Operator solutions for these rural hotpots can be inspired from the scenarios described above (originally developed for industrial IoT scenarios). Rather than security, reliability, and accountability as the main motivations for isolated deployment in industry, here, motivation for an isolated network is simply that existing traditional MNOs do not wish to invest and/or increase operational cost in rural network since additional revenues from this will be very limited, while other local actors do as the motivating factors are different, for instance, lowering the cost for social services. The first of the four deployments described above can be used provided that spectrum is available for the local operator (see previous section) and that roaming agreements are established (see next section).

A public entity such as a local government can invest in site infrastructure such as towers, shelters and electricity to house a MNO's RAN through regular Site lease agreements, sometimes for free. This is the "classic" way of lowering the investment cost for the MNO to increase coverage in specific areas of interest. Naturally, several MNOs can also be housed simultaneously. However, it can be seen that not even a free of charge lease agreement is always enough to motivate an MNO to invest in RAN & transmission, especially in more sparsely populated rural areas. The local government is also prohibited to subsidise the MNO's own RAN investments or operational costs, and therefore it might become necessary to deploy a NPN solution as the only remaining alternative.

4 REGULATORY ASPECTS AND NATIONAL ROAMING

In areas where multiple operators have spotty coverage national roaming can be used to enable improved area coverage. Although being a technically simple solution there are complex risks involved that are often highlighted, primarily by established operators. Poorly implemented national roaming can result in less willingness to invest in area coverage since doing so may assist prospective competitors. That said, rural area coverage is not always a well-functioning market and is anyway subject to heavy regulatory influence in many countries. The possibility of mandating geographically limited national roaming can be a lever for regulators wanting to incentivize MNOs to increase their investments in rural infrastructure. It should be noted that accepting incoming roaming traffic is not the same thing as roaming away from a network, especially for small privately-owned networks in rural areas.

One governmental requirement that could be argued for is for MNOs to be mandated to allow UEs roam away, into other national networks in regions where they don't provide enough coverage. This favours operators that build coverage in an under-served region and does not automatically enable operators with poor coverage to piggyback on other operators with better coverage. To facilitate this, regulators may need to decide on the roaming fees, and mandate that basic functions such as paging shall continue to work even when a terminal is visiting another network in the same country.

An excellent White Paper, recently published by Mentor addresses a number of solutions and regulatory changes related to establishing a ***rural neutral host mobile network operator***. These changes involve for instance national roaming in rural regions [22].

5 SUMMARY AND CONCLUSIONS

In this report, we have addressed the context and particular aspects of regulatory and network-operational models, that would improve rural coverage. We summarize the important aspects here.

1. Access to radio spectrum for small and local network operators must be made easy. Availability of new ***local licensing structures*** is crucial. Thresholds to acquire and use spectrum by new local actors must be lowered.
2. ***New rural operator models*** are needed. We can exploit ideas from the industrial developments in isolated non-public networks (NPNs) that are taking shape. Also, the concept of the rural neutral host mobile network is valuable.
3. Both the above networks (isolated local networks along with the neutral host networks [22]) rely on the value and further development of the concept of ***national roaming***. Users and end customers of national operators must be allowed to roam into the newly developed rural networks.
4. ***Sharing of existing infrastructure***. For the sake of cost efficiency, existing and new network infrastructure must be shared in the rural. In particular, sharing of the public network infrastructure and that associated with the emerging new security and safety networks (blue-light services) is crucial.

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