



LTE for Public Safety

Cost efficient upgrade from narrowband to broadband – is it possible?

Version 1.1

Table of Contents

1	Executive Summary.....	3
2	Evolution of Public Safety Networks.....	4
2.1	Existing Situation.....	4
2.2	Drivers and requirements for broadband Public Safety Networks.....	4
2.3	Overview of LTE Technology for Public Safety.....	6
3	Case Study Sweden.....	9
3.1	Description and used parameters.....	9
3.1.1	Study area.....	9
3.1.2	Planning parameters.....	9
3.1.3	Planning software.....	10
3.2	Study Results.....	11
3.2.1	Greenfield case.....	11
3.2.2	Greenfield TETRA and Migration to LTE PPDR.....	13
3.3	Discussion.....	13
4	Deployment models for LTE Public Safety networks.....	14
4.1	Overview of possible deployment models.....	14
4.2	Examples for deployment models.....	16
4.3	Decision criteria for selecting a model.....	18
4.4	Migration paths.....	18
5	Conclusion & recommendations.....	20
6	The Authors.....	21
7	The Companies.....	22
8	Coverage Maps.....	2
9	References.....	2
10	Abbreviations.....	3

1 Executive Summary

Public safety networks have been deployed to offer robust, fail-safe mission critical communications. Many government and public agencies around the world depend on their proper functioning. Since the 1990s these networks have evolved to offer secure digital communications for voice and basic data (messaging).

Nowadays the emergency situations as well as the daily routine of the public safety agencies require more and more broadband services so that life-saving information is securely and reliably transmitted between control centers and responders on the field. Unfortunately today's public safety networks were not designed to support such broadband requirements.

The answer to the demand for broadband public safety network is utilizing LTE technology. LTE is a mature mobile broadband technology (4th generation). It has been in commercial use since 2009. The technology is standardized by the 3GPP organization. In its latest standard release (release 13) the technology includes the foundation of functionalities needed to support public safety services. Further enhancements are planned in subsequent releases.

Having the right technology is not the only prerequisite for an efficient deployment of broadband public safety network. Compared to traditional narrowband networks (e.g. TETRA based) the broadband networks will require much denser network grid (more basestations). This itself poses budgetary as well as implementational and operational constraints.

To overcome those constraints public safety agencies have the choice to seek cooperation models with existing commercial mobile network operators and explore the possibility of network sharing in various sharing models. Thus synergies for both sides can be realized.

To achieve so, commercial networks will need to enable the mission critical functionalities in their networks as well as to increase the reliability, coverage and security of their networks. The exact scope of such modifications will depend on the range of services and requirements of the public safety agencies.

In this study we therefore present the key differences between narrowband and broadband public safety networks. We quantify the impact on network size when the network is built for broadband services. We also outline a variety of deployment models that can support an efficient deployment as well as migration steps to broadband public safety networks.

It is shown that broadband public safety networks utilizing 700MHz spectrum will need more than two times the amount of existing TETRA basestations. Cooperation between public safety network operators and public mobile network operator therefore will bring many mutual benefits as sharing parts of the public network can provide cost efficiency, economies of scale, access to highly skilled network professionals and speed up time to market.

2 Evolution of Public Safety Networks

2.1 Existing Situation

The majority of existing public safety telecommunication networks (also known as public protection and disaster relief, PPDR) is based on standards from the beginning of the 1990s. In Europe the predominant standard is TETRA with some countries using TETRAPOL. In North America the standard in use is P25. The standards offer very reliable narrowband service suitable for voice conversations (person to person, group calls) as well as basic messaging and limited data (kbits). As the networks operate in sub 400MHz frequency spectrum they have excellent coverage for low bitrate services. The amount of spectrum is typically 5MHz (380-385MHz uplink and 390-395MHz downlink) dedicated exclusively to public safety agencies.

Another distinctive characteristic of these networks is that they serve relatively small amount of users – e.g. police, national security, border control, ambulance, fire brigade, etc. (indeed from country to country it may vary). The coverage of these networks typically exceeds those of commercial mobile networks since it is required to cover populated as well as non-populated areas (related to the type of activities each user group is expected to perform. The security requirements are also higher – e.g. in TETRA there is a bidirectional authentication between users and basestations, something not common in commercial networks. A key distinction is also the traffic pattern - traditionally public safety networks have a rather symmetric traffic pattern (uplink – downlink is equal for voice communications), while in modern commercial networks the traffic is heavily asymmetric due to mobile users consuming more data in downlink than sending in uplink. In future it is expected that evolved public safety network will require more resources in the uplink due to sending information from the field towards the control centers e.g. video streams, high quality images.

There is no interoperability between public safety networks and mobile commercial networks – that is that a TETRA device cannot connect to GSM/UMTS/LTE and vice versa. Interconnection (when needed) happens via telephony exchanges (PSTN or similar). In the event of out of coverage a TETRA device can communicate directly to another TETRA device in its vicinity (an operation known as DMO) while such feature does not exist at present in commercial networks (as that will prevent billing). Nevertheless, the lack of interoperability is a drawback in particular when we consider that public safety networks require more and more capability to transfer large amounts of data within reasonable time.

Lastly it is worth mentioning that the equipment ecosystem (device and network) of public safety networks consists of a certain amount of relatively small companies, highly specialized in certain segments, but on the other hand exposed to economies of scale issues. On the other hand commercial network operators enjoy significant economies of scale – in particular the device ecosystem is very rich – there are hundreds of manufacturers of smartphones and devices of other form factors. On the network equipment side there are 5-6 very large companies producing thousands of basestations per year. Companies that provide core network equipment and applications solutions are similarly of significant amount.

2.2 Drivers and requirements for broadband Public Safety Networks

Demand for broadband PPDR networks is natural since it is related to the overall shift of the society towards digitization. Having digital voice communications and basic messaging is not

sufficient anymore. Almost all information that public safety agencies currently use, create and exchange is in digital form. Not only that, but the technology today enables certain work to be done more efficiently, if data can be transmitted reliably and fast. The situational awareness in case of an emergency can be improved drastically, if informational data streams (high quality video and audio) are available from the field to the control centers and vice versa. Dangerous activities like entering burning premises for initial surveillance or deactivating of explosive devices can be done by highly sophisticated robots or unmanned autonomous vehicles. These devices need wireless broadband connectivity for both visual, sensor and control functions. The range of services that will be positively enhanced in the presence of broadband PPDR network is immense [2], here we give a short summary.

- Full Database access (intranet, organization directory, architectural plans)
- Robotics/drone control (bomb retrieval, imagery delivery)
- Video (high quality streaming, live video feeds, multi streams – uplink and downlink)
- High resolution imagery (e.g. satellite images)

Different studies [2, 4] estimate that minimum cell throughput in worst conditions (cell edge) should be in the range of 1-2Mbps (with 10MHz FDD spectrum). Such data rates are impossible with TETRA/TETRAPOL/P25¹. LTE based technology satisfies such requirements. The radio network is not the only part that needs to be upgraded to support broadband services. The transmission links of narrowband networks are based on TDM links (e.g. E1 2Mbps) and the core switching elements are based on digital but not modern technologies. The evolution will require transmission links to be upgraded to IP based high capacity links and the core network elements to be evolved to SW applications build on top or next to state of art IMS ecosystem that allows for fast development and deployment of new PPDR services.

It is desirable that along with broadband services the PPDR network supports the existing narrowband and wideband services to avoid unnecessary costs to run multiple networks and devices in parallel. It is to be expected that hybrid situation can exist for certain period of time as part of the migration process. However the process of establishing broadband PPDR networks needs to start now since the existing narrowband networks (standards designed in the beginning of 1990s¹) are inadequate to support effectively the operation of public safety agencies.

Evolving to broadband capable network has to happen in line with the strict reliability and security requirements of PPDR networks. Contrary to commercial mobile networks the failsafe operation on all network levels must be ensured in at least 99.99% of the time. Individual elements must have 99.999% reliability [5]. The deployed hardware and software needs to be redundant and hardened. Security requirements are severe to prevent any kind of spoofing, eavesdropping, jamming and denial of service, etc.

¹ Note: Some standards like TETRA evolved to support moderate wideband rates, however for economic reasons not many public safety networks upgraded to the latest standard. ETSI TCCE decided that instead of pursuing TETRA Release 3 the next versions should be implemented utilizing 3GPP LTE as radio bearer technology.

2.3 Overview of LTE Technology for Public Safety

Long Term Evolution (LTE) is the current state of art standard for mobile commercial communications. Since its inception in 3GPP release 8 it has been enhanced in subsequent standard releases (release 13 is the current one, also known as LTE Advanced Pro) to provide further features and functionalities.

The key characteristics of LTE technology are flat architecture (few network elements), All-IP based (IP based communications end to end) and very flexible towards spectrum utilization (in terms of spectrum channel size and frequency spectrum band). It has superior spectrum efficiency and broadband capabilities compared to previous radio communication standards due to usage of advanced features such as OFDMA, MIMO, turbo coding, 64QAM and 256QAM modulation, carrier aggregation. The peak theoretical data rates achievable with commonly available devices in 20MHz FDD spectrum is 150Mbps (downlink direction) and 50Mbps (uplink direction). Advanced devices using more spectrum and features can achieve beyond 400Mbps downlink and 100 Mbps uplink.

The initial focus of commercial operators was to use LTE as a complementary high speed data only network next to their GSM (2nd generation) and UMTS (3rd generation) networks. With the objective to use networks more efficiently and to free up spectrum resources (refarm spectrum) operators have started to introduce the whole range of mobile services (voice and video calls, short messages, internet data) over LTE. This is facilitated by deploying IMS platform(s) that handle the service layer over the IP layer of connectivity provided by the LTE radio access.

In addition to the standard unicast services (a service per user) LTE includes features that allow for broadcasting. From 3GPP release 10 the LTE-Broadcast (MBMS) feature is introduced and enhanced. It allows for efficient transmission of content simultaneously to a group of users.

With respect to public safety services LTE doesn't have the full portfolio of services but the standardization community is working to close the gap. In particular the following services are under development

- Mission critical push to talk (standardized in 3GPP Rel.13), with group call setup within 300ms and max end to end delay of 150ms [6]
- Group communications system enablers (3GPP Rel. 12 and 13)
- Proximity services (ProSe) – the equivalent of TETRA DMO (3GPP Rel. 12 and 13)
- Isolated operation for public safety (operation with a certain area which has been disconnected from the main network) (standardized in 3GPP Rel.13)
- Mission critical video and data (standardization planned for 3GPP Rel. 14)

The LTE network should be interoperable with existing PPDR networks (TETRA / TETRAPOL / P25). The interoperability is two-fold – on the service layer there shall be an interface (s) between LTE public safety applications and the narrowband PPDR networks. On the devices – the device shall be able to connect to both networks. It is expected that narrowband PPDR networks will continue to exist up until 2025 [7].

In terms of frequency spectrum it is expected in Europe to use sub-1GHz bands. The CEPT ECC in its report [ref to ECC218] recommended a flexible harmonization focusing on the

400MHz and the 700MHz as most likely spectrum bands. The 400MHz band is already used for a variety of PMR and communications services. The availability of contiguous 10MHz is limited. In the 700MHz up to 30MHz FDD spectrum is expected to be made available across Europe for commercial and/or hybrid (commercial / public safety) use. In addition commercial operators may decide to offer PPDR services utilizing their existing spectrum² (e.g. 800MHz).

An example LTE based PPDR network is presented below. For clarity only the main functional elements are depicted.

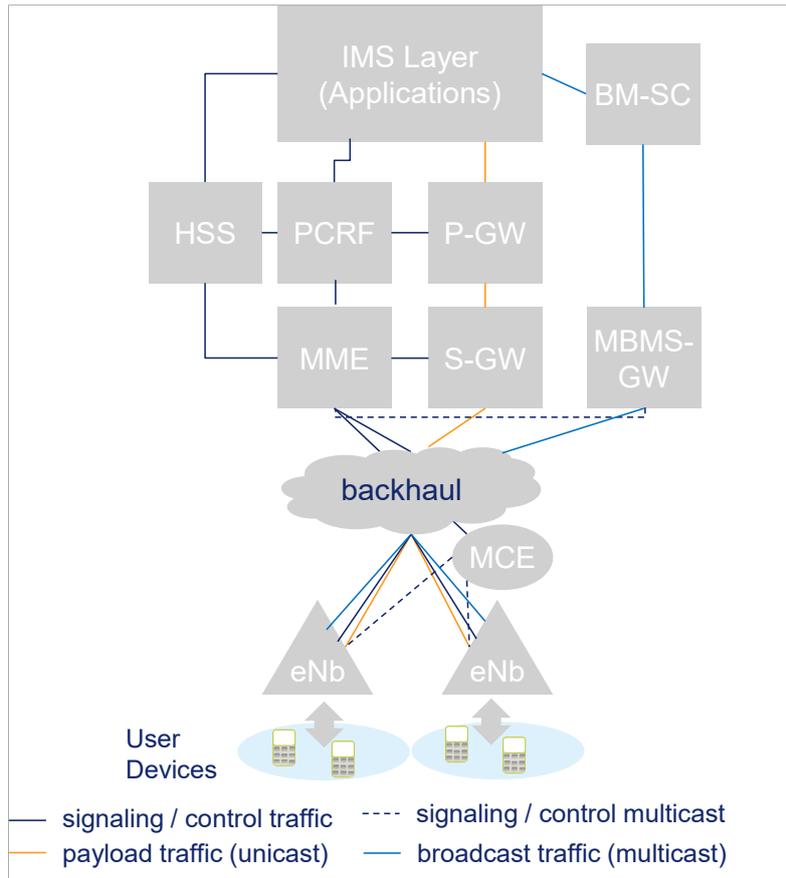


Figure 1: LTE PPDR Network architecture

The involved network entities and elements are described below.

² Note: This is the case e.g. in the UK for the ESN public safety network whereby EE will utilize its 800MHz spectrum

Table 1: LTE network elements

Network element	Description	Network element	Description
eNB	eNodeB, radio access node	MCE	Multicell coordination entity (used in broadcast)
MME	Mobility Management Entity	S-GW	Serving Gateway
P-GW	Packet Data Network Gateway	MBMS-GW	Multimedia Broadcast Multicast Service Gateway
PCRF	Policy and Charging Rules Function	HSS	Home subscriber server
IMS Service Layer	Internet Protocol Multimedia Subsystem – a multilayer of service applications including MCPPT and ProSe	BM-SC	Broadcast Multicast Service Center

Please note that not all elements are shown, in particular transmission topology is omitted since it can be quite different from operator to operator. Backhaul is one of the critical components of the transmission network linking the basestations to the next point of transmission aggregation.

3 Case Study Sweden

3.1 Description and used parameters

3.1.1 Study area

Planning is done in the county of Östergötland in Sweden, with an area of about 14 500 km².



Figure 2: Landscape in Östergötland, source: Wikipedia, [Artifex](#)

The relief is mixed – large part of the county is occupied by plains and lakes, with some parts in the north and south containing hills and forests. More than 400,000 people live in the county. Part of the east side has access to the Baltic Sea while part of the west side borders with the second largest lake in the country – Vättern.

3.1.2 Planning parameters

The case study examines the required number of basestations for TETRA [1] and LTE PPDR respectively to achieve the required coverage. Several scenarios are defined – indoor and outdoor coverage, moderate and high coverage probability target as well as different user equipment type – handheld (HH) or mobile station (MS) placed in car (with outdoor antenna).

For both networks the coverage planning is done for the uplink direction (device to basestation) since it is the limiting factor. For the TETRA network the design was done for a typical voice call service, while for LTE PPDR the design was done for a 2Mbps data service in worst condition (cell edge).

Corresponding to the scenarios different link budget calculations are performed. The key parameters are listed in the table below.

TETRA was planned in its native 380MHz band, while for LTE 700MHz was used as per the ECC recommendation [4].

Table 2: Planning Parameters

Parameter	TETRA	LTE PPDR
Frequency [MHz]	384	738
Nominal bandwidth	25 kHz	10 MHz
Transmitter power [dBW]	10 for MS 0 for HH	-7 (23 dBm) for both MS and HH
Transmitter antenna gain (including cable) [dBi]	0 for MS -5 for HH (including body loss)	5 for MS -5 for HH (including body loss)
Transmitter antenna height [m]	1.5	1.5
Information type, data rate	Voice	2 Mbit/s
Building penetration loss for indoor coverage representative for city buildings [dB]	15	15
Receiver antenna gain (including cable) [dBi]	7.5 (omni)	16 (sectorised)
Receiver antenna height [m]	48	48
Receiver diversity gain [dB]	3	3
Receiver sensitivity [dBm]	-106 (dynamic)	-101
Resulting effective receiver sensitivity [dBm]	-109	-104
Planning margin (PM) for desired coverage [dB]. At least the level [Sensitivity] + [PM] is to be achieved at all points within the desired coverage area.	10	10
Planning and presentation level [dBm]	-99 (outdoor) -84 (for indoor margin)	-94 (outdoor) -79 (for indoor margin)

3.1.3 Planning software

WRAP International's software [3] for radio spectrum management & radio network planning was used (see www.wrap.se for more information). Some important settings as defined in the following were used.

Geographical data: Ground height data with 50 m horizontal and 1 m vertical resolution, terrain classification data with 25 m resolution (using height additions and electrical properties of the terrain classes in the propagation calculations)

Propagation model: Detvag90 with selection GTD – Geometrical Theory of Diffraction. The model is developed by the Swedish Defence Research Agency.

Cost and Coverage Optimiser: Planning was done using this tool of WRAP. The desired area to cover, the allowed placement area of base stations, the required percentage area coverage (in this case set to 95% and as alternative 99% of desired area), planning margins are defined. It was run in greenfield planning mode, which means that the result in terms of the number of base stations is the very minimum required to cover the desired area. *Chapter 7 gives some more information on this tool.*

Migration TETRA-to-LTE: A migration alternative is conceivable where existing TETRA base installations are complemented with LTE and new LTE bases are established at best-sited greenfield locations. Calculations were performed to exemplify the amount of additional complete LTE installations.

Coverage: To illustrate the resulting coverage from the optimised number and location of the base stations the Coverage tool was used. The resulting coverage is presented in the map appendices.

3.2 Study Results

3.2.1 Greenfield case

The coverage optimization gave the following results.

Table 3: Greenfield Planning Results

Parameter	TETRA (95%)	TETRA (99%)	LTE/PPDR (95%)	LTE/PPDR (99%)
Number of base stations, HH outdoor	106	166	239	399
Number of base stations, HH indoor	647	1034	1479	2553 (gave 98% coverage)
Number of base stations, MS outdoor	19	31	72	119
Number of base stations, MS indoor	89	145	426	684

The % values refer to the area coverage probability.

The coverage maps for two of the cases are shown in chapter 8. The blue colour in the maps represents a 15 dB higher signal level than the planning level of -94 dBm. This for instance indicates the indoor coverage (15 dB building penetration loss), or the coverage for a much higher data rate.

The LTE/PPDR map for the 99%/HH Outdoor case (399 base stations) presents several colours for various received signal levels in the range -79 dBm to -94 dBm. The covered areas in km², covered area in percentage of desired area, covered population and covered percentage of population for the different signal level values are shown in the following figure. Population statistics are within the red rectangle.

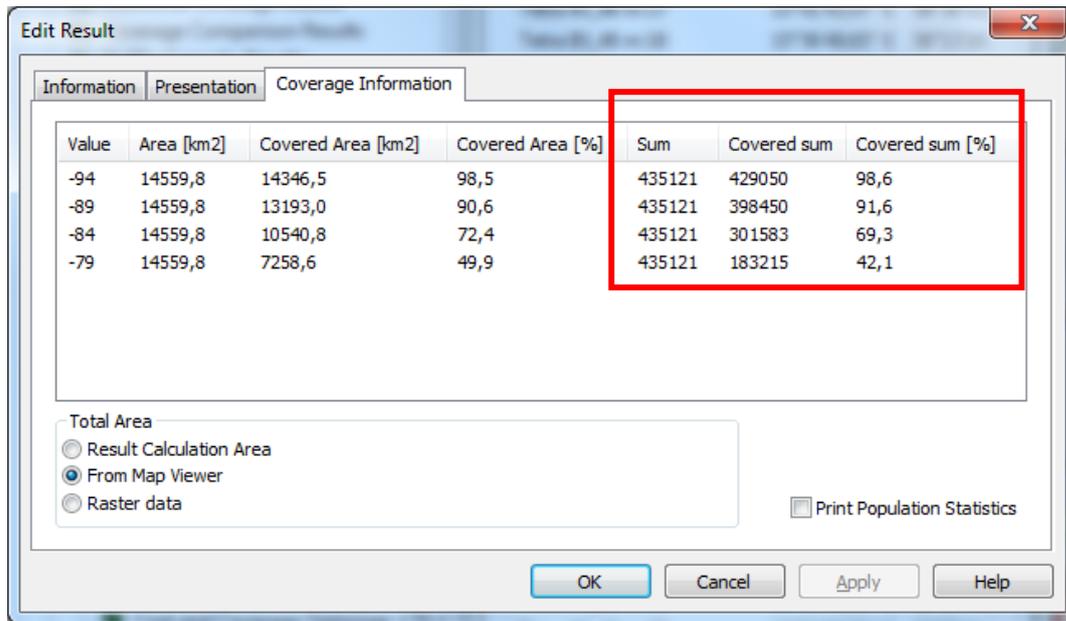


Figure 3: Coverage Information, source WRAP tool

The coverage optimization³ can be performed to automatically favour populated areas. This would have resulted in a much higher population coverage at the expense of the area coverage.

As expected LTE/PPDR requires many more base stations to provide the similar level of area coverage as TETRA. The reasons for this are mainly:

LTE/PPDR has much less RF power output than TETRA (10 dBW for TETRA, only -7 dBW for LTE). *Note: LTE/PPDR may include a higher power mobile terminal with about 10 dB higher power. It was not modelled in these examples.*

Using 750 MHz instead of 390 MHz gives higher propagation loss due to the higher frequency

Higher data rate for LTE/PPDR – requires higher received signal level.

To compensate for the disadvantages in the link budget the LTE/PPDR case that was modelled here used higher receiver antenna gain in the base (16 dBi instead of 7.5 dBi) and higher transmitter antenna gain in the car for the MS case (5 dBi instead of 0 dBi).

The building penetration loss (BPL) of 15 dB is naturally not reasonable to apply for all of the coverage area of interest in this case. Much of the area is rural countryside environment with few and far between buildings where the BPL is much less than 15 dB and it would be over-kill to design the network for indoor coverage in all of the countryside houses. But the values

³ Note: The software allows for performing all of this optimized coverage planning automatically if suitable geographical data is available. The BPL can be set individually for each terrain code, which means that built-up areas that are assigned a high BPL will get a higher density of base stations. If suitable geo-data is not available the planning can be done in two steps – first by defining and running the areas where for instance indoor coverage is required, then re-using the resulting base stations and running the planning for the rural areas where indoor coverage margin is not required.

are of interest anyway since they give an indication of what it takes to give indoor coverage in wide-spread urban areas.

3.2.2 Greenfield TETRA and Migration to LTE PPDR

This example illustrates existing TETRA base stations that are complemented with LTE and new LTE base stations are established at best-sited greenfield locations. The TETRA base stations were optimized for handheld outdoor coverage and all the TETRA bases were re-used. Additional LTE bases were placed optimally to also give indoor coverage.

Table 4: LTE PPDR re-using TETRA basestation locations

Parameter	TETRA (95%)	TETRA (99%)	LTE/PPDR (95%), re-used TETRA	LTE/PPDR (99%), re-used TETRA
Number of base stations, HH outdoor	106	166	287	428

The greenfield planning for LTE/PPDR required much fewer base stations for the same coverage target. This is due to the “existing” TETRA sites not being optimally placed to provide LTE coverage, thus requiring more additional LTE sites.

3.3 Discussion

As it can be seen in Table 3 the required basestations to achieve good indoor coverage amount from several hundred to even above 2000 in the most extreme case (LTE PPDR for 99% area coverage). To deploy such amount of basestations will be quite challenging from cost, time and operational perspective. In our view almost certainly it will be avoided by most PPDR operators.

On the other hand, deployment for MS for outdoor coverage might lead to insufficient performance for a large range of service that will be used with handheld devices (smartphones, tablets, body cameras, etc.)

Thus we are expecting that PPDR operators most likely will be selecting a network size corresponding to a good outdoor coverage for handhelds while fulfilling certain area coverage criterion. The higher the coverage requirement the more basestations will be required – in our study the amount ranges from 239 to 399 (95% to 99% coverage area probability).

Still compared to equivalent TETRA deployment the amount of LTE basestations is a factor of 2.25 to 2.40 higher. That means that even if existing narrowband networks are planned for similar coverage requirements the site grid is too sparse to be used to co-host LTE PPDR basestations. Additional sites will be needed to ensure that the LTE PPDR network is compliant with the target coverage parameters.

It is worth mentioning that augmenting an existing network will require a very detailed planning so that the amount of new sites are kept to the possible minimum. As pointed out the chapter 3.2.2 the TETRA grid might not be fully suited so additional sites for LTE PPDR compared to the greenfield LTE PDDR case will be needed (~7% more).

4 Deployment models for LTE Public Safety networks

4.1 Overview of possible deployment models

Public safety agencies and PPDR operators are facing a variety of choices when deciding for the most optimum deployment model that fits their organization's mission and goals. It has to be emphasized that those can be quite different from a country to country (and even in a country between various organizations).

Here we would describe three broad options that either exist already or can be a future model. Within these options a significant variation of the scope and setup is possible so that it fits best the future needs of the PPDR operator (driven by demand to offer broadband PPDR services).

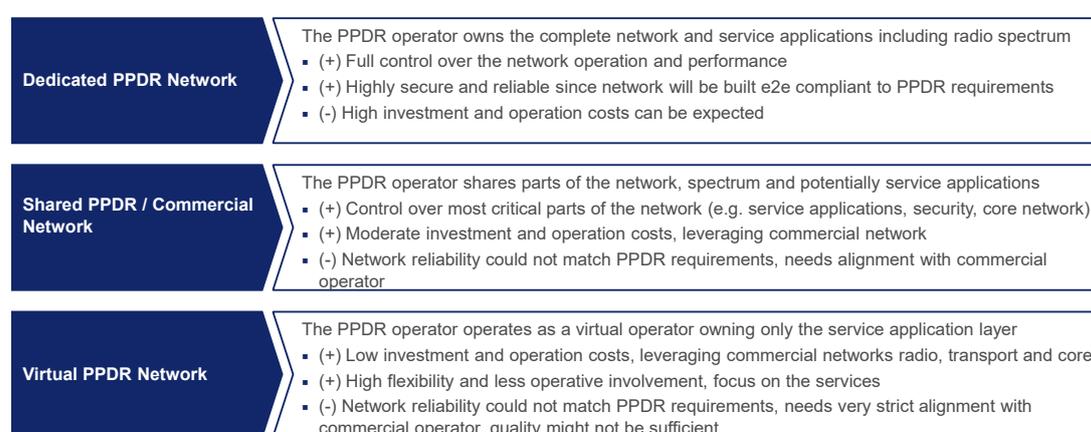


Figure 4: Deployment models for PPDR operators

The first option is the dedicated PPDR network. This model is based on the traditional approach of fully independent network whereby all equipment and infrastructure is owned and operated by the PPDR operator (who might itself be public or private entity). Frequency spectrum, radio access basestations, transmission, core network and applications are owned and operated by the PPDR operator. The control rooms are typically under the control of the PPDR user organizations (e.g. police, ambulance, fire brigade). The network is built according to stringent PPDR requirements for security, reliability and coverage.

As outlined in the case study in chapter 3 for traditional narrowband PPDR networks this seemed to be a straightforward solution considering the size of network (that is radio basestations, transmission, core network elements) was relatively small. Should a narrowband PPDR network evolve to broadband PPDR network much more infrastructure will be needed and hence the cost and complexity of deployment will rise. Additional requirement for the staff is the building of knowledge and expertise to deploy and operate an LTE based all-IP PPDR network.

The second option is the shared PPDR network. It is shared with a commercial mobile operator (can be with more than one). What parts of the network to be shared is up to an agreement and specification between PPDR operator and the commercial operator. The level of sharing can also change with time – e.g. in the beginning the PPDR operator keeps its narrowband TETRA network operational while at the same time sharing with the commercial operator the broadband PPDR network (LTE based). After some time once all needed TETRA features can be securely and reliably offered over LTE parts of the TETRA network can be switched off

(radio basestations) while keeping the core network and service applications. An exemplary split for the evolved PPDR network is presented below.

Table 5: Split of network elements between PPDR and commercial operator

PPDR operator	Commercial mobile operator
Core network including HSS, MME, S-GW/P-GW, PCRF, secure gateways (IP-Sec)	Radio frequency spectrum (e.g. 700MHz), radio sites and eNodeBs
Service applications based on IMS including MCPTT for voice and video, access to databases, ProSe server etc.	Backhaul and backbone transmission equipment and links (IP)
	Network OSS

In this option both parties benefit from shared utilization of the radio access and transmission, enabling to reduce cost and use resources more efficiently. The major cost drivers are the radio sites, basestations and transmission. A critical benefit is the time to market – mature commercial networks have a footprint exceeding 95% population coverage. Even if this is not sufficient and expansion is required the effort to buildout the additional sites is much less compared to building a complete new network. On the downside could be that the commercial network is not built with the stringent requirements of PPDR for security and reliability. To a certain extent that can be mitigated by enhancing the existing infrastructure (e.g. ensuring power availability from different sources as well as backup, more than one backhaul link, adding extra redundancy in key network elements). Software features that enable the prioritization of PPDR users over the commercial users is mandatory.

The third option is the virtual PPDR network. As the name suggests the PPDR operator offers services utilizing the network of a commercial mobile operator. In the very extreme form of this setup the PPDR might only keep and control the service layer with the specific PPDR applications while all other network elements are under the control and operation of the commercial mobile operator. Technically this is realized under the scheme of MVNO (mobile virtual network operator). In particular Europe has been a leader in the launch and operation of MVNOs for commercial services since mid 2000. [11]

Similarly to the second option this one also allows for a very cost efficient and fast launch of PPDR services over existing commercial mobile network. On the drawback side is the level of security and reliability offered by the host operator. Typically MVNO platforms are designed for mass market mobile services. Introducing PPDR specific features, high level of prioritization and end to end support might prove technically challenging and in some cases non-feasible.

An exemplary split for the evolved PPDR network is presented below.

Table 6: Split of network elements between virtual PPDR and commercial operator

Virtual PPDR operator	Commercial mobile operator
Service applications based on IMS including MCPTT for voice and video, access to databases, ProSe server etc.	Radio frequency spectrum (e.g. 700MHz), radio sites and eNodeBs
	Backhaul and backbone transmission equipment and links (IP)
	Core network including HSS, MME, S-GW/P-GW, PCRF, secure gateways (IP-Sec)
	Network OSS

4.2 Examples for deployment models

FirstNet in the United States of America

The FirstNet in the USA is planned to be fully operational in 2022[8]. It will be the first nationwide public safety broadband network in the USA. It plans to serve up to 4 million potential users (first responders) from 60,000 public safety agencies, 3144 counties and 566 tribes in urban and rural areas. The network will offer full range (narrowband, wideband and broadband) services over the same infrastructure.

Initial funding of 7bn USD secured from the government, subsequent funding via spectrum auctions until 2022. It will use 2x10MHz spectrum bandwidth in band 14 (700MHz).

First deployment is planned to start in 2017. Scope of work will be handed over to subcontracting entities via comprehensive request for proposals (RFP) and contract awards.

Broadly speaking the FirstNet will be deployed as a dedicated PPDR network. Certain cooperation with existing network operators can be expected though.

Emergency Services Network in the United Kingdom

The Emergency Services Network (ESN) is required by the UK's Home office. It comes as a replacement of the narrowband TETRA based Airwave network (private entity serving the government agencies). ESN will enable integrated critical voice and broadband data services[9] that are:

- enhanced: to provide integrated broadband data services
- flexible: to better match and be responsive to user needs
- affordable: to address financial pressures on central and user budgets

It plans to serve 300 public organizations and 300,000 users. Contrary to the USA example the Airwave network is a nationwide network thus the new network broadband ESN needs to match (and outperform) the existing coverage of the narrowband network. The deployment will be in stages. Between 2015 and 2017 – preparation of the ESN network, end of 2017 – end of 2019 transition from narrowband PPDR to ESN network, 2020 – PPDR only on ESN network.

The partners that build the network are three – a project management and delivery partner, a system integrator and user services partner, and a mobile services (network side) partner.

Broadly speaking the ESN will be deployed as a shared PPDR network. The provider of the frequency spectrum and most of the network components is EverythingEverywhere (EE), the largest commercial mobile operator in the UK. The PPDR will use 800MHz spectrum. The system integrator and service layer provider is Motorola Solutions. A critical success factor will be that execution of the time plan is strictly followed since in the transition period public safety organizations have to pay to both the narrowband and broadband networks.

Astrid Network in Belgium

Astrid is a government owned PPDR operator that offers both narrowband and broadband PPDR services [10]. For the narrowband services it has deployed and operates a nationwide TETRA network.

In parallel Astrid offers a broadband PPDR service utilizing the commercial mobile networks via the mechanism of MVNO and roaming. They have setup a virtual network “Blue Light Mobile” that enables users to connect to a preferred commercial network for broadband services (3G or LTE). Should the preferred network be unavailable the user can connect to other available commercial network (via national roaming). The exchange of data is secured over VPN that ends up in Astrid data center and from there via IP connection to the end user’s organization. The users must purchase a separate device from the narrowband device (e.g. laptop or tablet), Astrid offers a list of validated devices.

Broadly speaking the broadband network of Astrid is deployed as a virtual PPDR network. It is focused to provide secured data connectivity for certain applications (dispatching applications, videos and photos, access to organization’s databases and services). In the aftermath of the Brussels terrorist attacks (March 2016) which lead to saturation of the commercial mobile networks as well as capacity bottlenecks of the TETRA network for voice services Astrid is in discussion with the commercial networks how to enable also prioritized voice services over the MVNO setup [10, press release from May 18th, 2016].

4.3 Decision criteria for selecting a model

Public safety agencies are facing the question which deployment model is most suitable for their organization. While unfortunately there is no single answer to this question, the public agencies could follow a set of questions and then analyze the answers to a set of decision criteria.

There are at least three major questions to be asked:

- What kind of services and for what type of users the target broadband PPDR network shall be designed and constructed?
- What is the timeframe in which the network shall be deployed and in operation considering migration steps (if applicable)?
- What is the maximum budget for deploying and operating the network?

The larger the list of services and/or type of users the larger the scope and hence complexity of the PPDR network will be. Shorter execution timeframe might face technological challenges – e.g. certain functionalities not available in LTE standard while on the other hand a longer execution timeframe including migration from narrowband to broadband network could result in significant operational costs for running two networks in parallel. Last but not least the amount of budget will shape the deployment model selection – e.g. a very restricted budget might necessitate a virtual PPDR network deployment.

4.4 Migration paths

Existing PPDR operators with narrowband communications network will face the challenge of migration to broadband PPDR sometime in the future. Depending on the timeframe several options will be available:

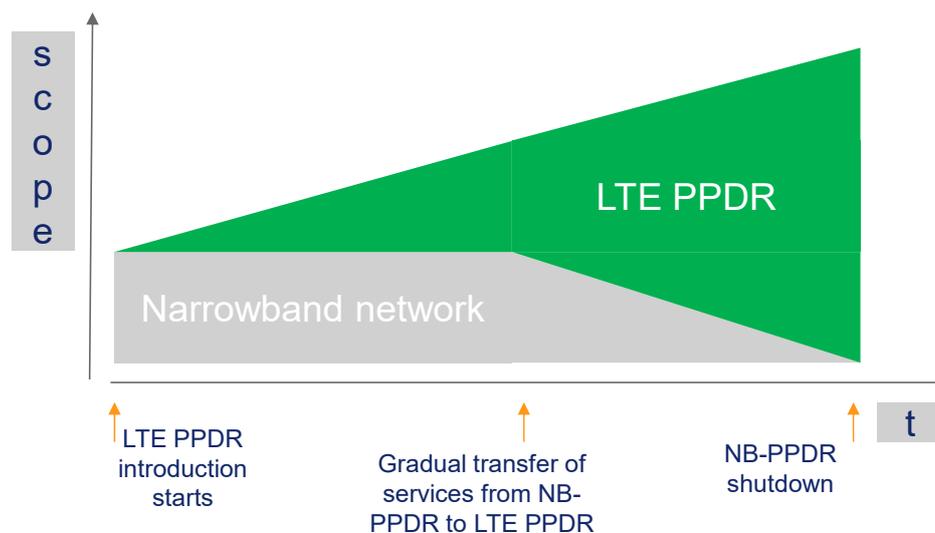


Figure 5: Migration timeline

- Immediate transfer of all PPDR services to LTE PPDR network once the network is running and shutdown of NB-PPDR (e.g. TETRA)

- Parallel operation of Narrowband PPDR and LTE PPDR for some time then gradual migration of all services to LTE PPDR and shutdown of NB-PPDR

The timeframe is the first important decision criterion – LTE PPDR does not support as of today (beginning of 2017) all required PPDR features. Considering the 3GPP standardization timelines (mainly Rel. 13 and 14) and equipment manufacturers' product readiness it will be safe to assume that complete ecosystem could be available by beginning to mid of 2018.

However it is important to emphasize that existing PPDR operators have in the field user equipment that will not be capable to be upgraded to LTE PPDR via local or remote upgrade. The lifetime of such equipment and the rate of change from old to new user equipment need to be considered as important factors (in some cases it could be more costly to swap at once all user equipment than to run in parallel two networks and gradually do the swap of user equipment).

A good example to be observed is the ESN network deployment in the UK – the migration from NB-PPDR (TETRA) to LTE PDDR is planned for a period of several years.

Some infrastructure of existing PPDR operators - site locations, passive infrastructure such as power supply, power backup, auxiliary systems, data center facilities maybe re-used to a significant extent. Other infrastructure such as transmission links will need to be upgraded to support IP communications. Security nodes and gateways will be required to ensure end to end protection against eavesdropping, spoofing and tampering of the communications. LTE PPDR basestations, antennas (specific to the operating spectrum band, e.g. 700MHz), core and service application platforms very likely will be newly deployed. Therefore the target LTE PPDR network will be composed of a mixture of existing and new infrastructure.

Integration with existing systems as well as interconnection to ensure all needed communication flows (e.g. interconnection between narrowband and broadband PPDR networks, with commercial networks, with other government networks) need to be planned and executed according to the available budget and resources.

5 Conclusion & recommendations

Public safety networks are in transition process to support more and more broadband services. The existing narrowband networks (like TETRA or P25) cannot be upgraded to support broadband services. On the other hand LTE based PPDR networks are not yet fully capable to support specific mission critical communications like group voice and video calls, device to device, operation in isolated mode. Nevertheless those functionalities are expected to be available already in 2017 (mid – end year). Latest by 2018 the whole ecosystem – from devices to service applications shall be available for sourcing and deployment.

The broadband services will require a denser site grid compared to narrowband networks. The expansion of the network in terms of site, basestations, and transmission links will require substantial investment, effort and skillset. Hence a various deployment models can be envisaged leveraging cooperation with commercial mobile network operators. Such shared network models can vary in scope and responsibility split between commercial and PPDR operators to suit the needs of public safety communications while achieving a win-win situation - cost efficient broadband PPDR network deployment as well as additional revenue stream for the commercial operator(s).

Based on our results we are recommending that public safety agencies and commercial mobile network operators consider and investigate the partnership models that are most suitable to their needs and could bring mutual benefits.

Whatever model is selected there will be a need for a substantial analysis on technical and business requirements. Independent advisory is crucial to ensure that the interests of all stakeholders are treated fairly and the proposed solutions are tangible, realizable and cost efficient.

In the initial phase of the broadband PPDR network planning it has to be decided what radio spectrum will be used, what services are to be enabled, which part of the network will be shared and which will be dedicated. The next step is to plan the migration steps (for existing PPDR operators). Once all the plans are available it is recommended to initiate a tender process so that a competition is encouraged between vendors and service providers ultimately ensuring that the best solution will be available at the right budget.

6 The Authors

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Detecon and WRAP are your trusted partners with many years of experience in the field of mobile telecommunications.

7 The Companies

7.1 Detecon International GmbH

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Our company's history is proof of this: Detecon International is the product of the merger of the management and IT consulting company Diebold, founded in 1954, and the telecommunications consultancy Detecon, founded in 1977. Our services focus on consulting and implementation solutions which are derived from the use of information and communications technology (ICT). All around the globe, clients from virtually all industries profit from our holistic know-how in questions of strategy and organizational design and in the use of state-of-the-art technologies.

Detecon's know-how bundles the knowledge from the successful conclusion of management and ICT projects in more than 160 countries. We are represented globally by subsidiaries, affiliates, and project offices. Detecon is a subsidiary of T-Systems International, the business customer brand of Deutsche Telekom. In our capacity as consultants, we are able to benefit from the infrastructure of a global player spanning our planet.

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The rapid development of information and telecommunications technologies has an increasingly significant influence on the strategies of companies as well as on the processes within an organization. The subsequent complex adaptations affect business models and corporate structures, not only technological applications.

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Detecon has developed a comprehensive network planning tool – **NetWorks**

NetWorks allows you to analyze and plan networks creatively and efficiently. You can use a comprehensive range of specific products which have been implemented based on a standard multi-layer concept for different technologies and different services. **NetWorks** has an efficient model and data management and simplifies the handling by the graphical-tabular user interface.

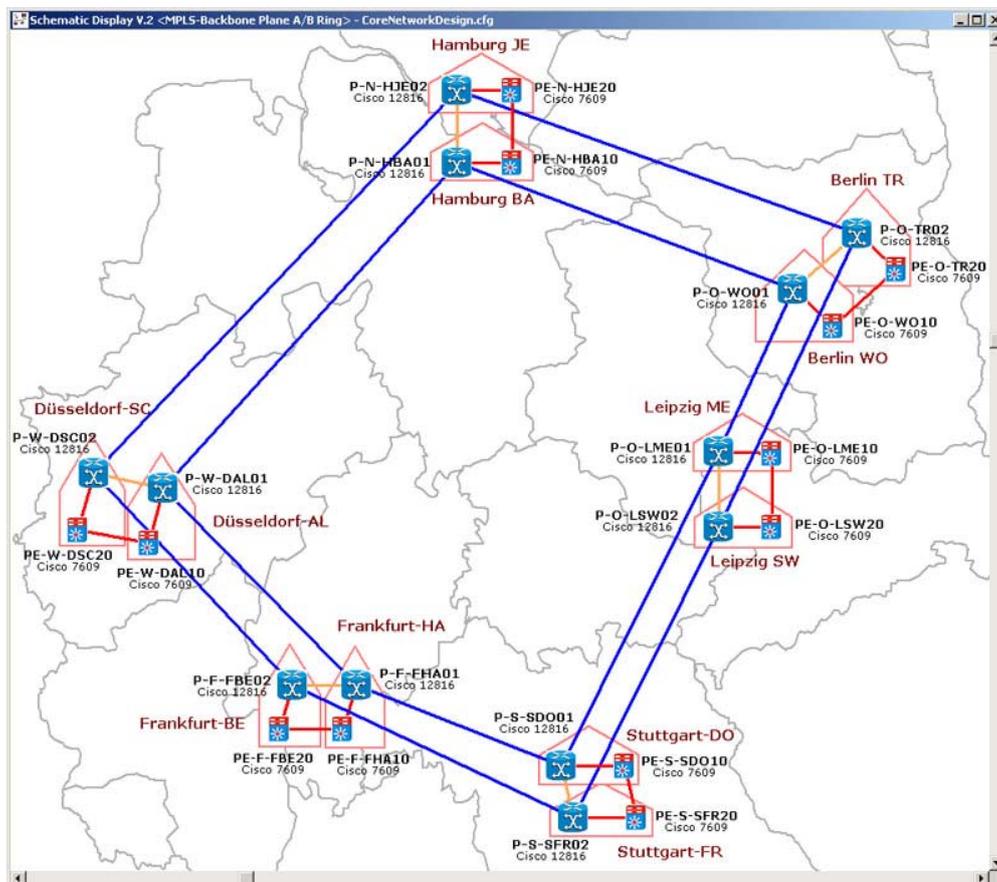
The software tools of the **NetWorks** family support the analysis, planning, and optimization of networks using:

- 2G, 3G, and 4G wireless technologies such as GSM, GPRS, UMTS, WiMAX, HSPA, LTE, LTE - Advanced
- TDM and WDM transport technologies (SDH, DWDM)
- Packet-based technologies (IP, MPLS, ATM, Ethernet)
- Modern fixed access technologies (PON, DSL, Ethernet)

NetWorks has an efficient model and data management and simplifies the handling by the graphical-tabular user interface.

With its geographical, schematic and table view the user has access to the data and topology of his networks.

For more information – <https://www.networks.detecon.com/drupal/en/en-content-networks>



7.2 WRAP International AB

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WRAP International provides a comprehensive portfolio of expert consulting and software products for Radio Network Planning and Optimisation as well as Spectrum Management. The WRAP software provides efficient frequency management and radio network planning support for organizations ranging from telecommunication authorities to network planners. WRAP supports the planning, implementation and operation phases of systems for microwave point-to-point, point-to-multipoint, broadband wireless access, wireless local loop (including WiMAX), analogue and digital sound and television broadcasting, land mobile, mobile telephone, radar, navigation, aeronautical communication, HF communication, satellite links and more. The efficient tools of WRAP provide cost-effective network designs with small manpower efforts. The company has customers in more than 35 countries world wide.

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WRAP International also offer specialized tailor made services for setting up a robust regulatory framework. Our skilled team provide assistance in reviewing and preparing policies, processes and regulations in the wide domain of regulatory issues, including but not limited to Rules of Procedure, Complaints Procedure, Appeals Procedure, Quality of Service criteria, Interconnection & Access, Roaming Agreements. Tariff Policy, Tariff Regulation, Cost Assessment & Modelling, Lawful Interception & Cyber Security, Competition & Barriers to Market Entry, Universal Service, Spectrum Pricing & Allocation, Spectrum Licensing & Auctions, Satellite regulations, Site Access & Site Environmental, Infrastructure sharing and co-location, OTT Regulation, Digital Broadcast, Number portability.

Radio Network Planning and Optimization Services

WRAP International provides a comprehensive portfolio of services related to Cellular Radio Network Planning and Optimization. Examples are Network Benchmarking, Network Audit, Spectrum Monitoring, Load Balancing between technologies (2G, 3G, 4G), Global RAN Parameter Standardization & Clean Up.

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TELECOM NETWORK OPERATORS

Cost and Coverage Optimiser

Reduce manpower costs, minimise investments and maximise coverage. All with one tool – WRAP.

Making accurate cost estimates for new and expanded radio networks is a time-consuming and manpower-intensive effort. Even very skilled radio planners have great difficulties to achieve efficient and optimum network plans. Let them use WRAP Cost and Coverage Optimiser to ensure the lowest investments for your Cellular, TETRA, WiMAX or Broadcast networks.



Straightforward application • Complex analysis • Coherent results

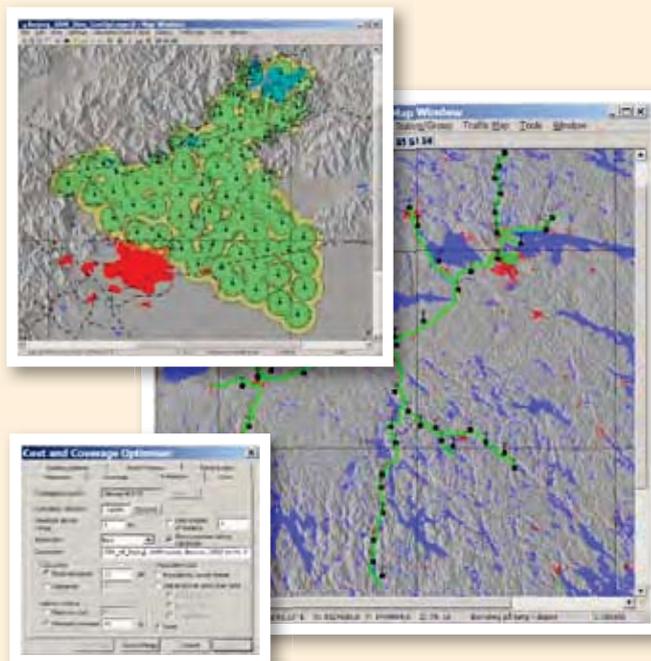
WRAP IS A COMPREHENSIVE radio planning system with many functions to efficiently support planning of any area-covering and point-to-point/multipoint network. The Cost and Coverage Optimiser is a highly useful tool when establishing the nominal radio plan for cost and budget estimates, followed by the detailed radio plan in the implementation phase and later when expanding and optimising the operational network.

THE COST & COVERAGE OPTIMISER automatically places base stations at existing sites, or at best-selected greenfield sites, at optimum antenna heights under variables that define investment and operation costs. Terrain features as given by geographical databases are accounted for through accurate propagation models.

The optimisation can be done to give best coverage of population, definable areas, roads, railways and points. Coverage redundancy for additional network robustness can be defined. The automatic optimisation can be done within a budget limit to give best coverage for the investment, or within a coverage requirement to give the investment cost.

The process ensures that the network is designed for the lowest cost and gives a large reduction in the required manpower for the planning process.

USING THE COVERAGE TOOL ALLOWS clear visualisation and verification of the coverage that was achieved, in 2D or 3D presentations. This tool is in itself very flexible to use for all kinds of coverage calculations.



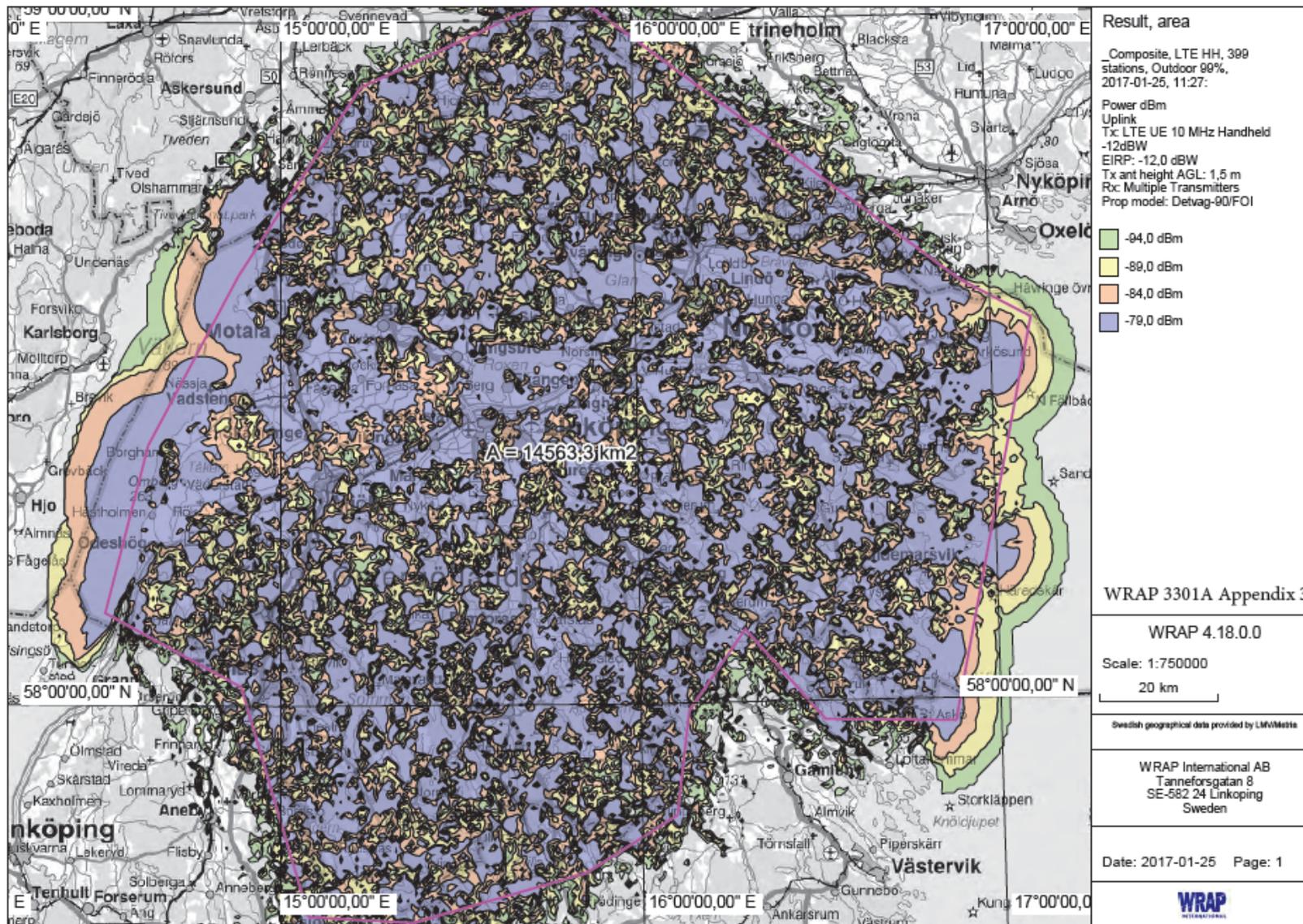
USE WRAP TO COMPLEMENT your existing radio planning software. Flexible and quick import/export functions allow easy exchange of data with other applications. Create the nominal radio plan quickly in WRAP, export it to your preferred planning tool for further refinement or check your existing plan by importing it to WRAP.

THE EFFICIENT TOOLS OF WRAP give a cost-effective network design with a small manpower effort. Select these tools to give large cost reductions for area coverage planning:

- Coverage
- Cost and Coverage Optimiser
- Map Data Manager

8 Coverage Maps







Result, area

- Composite, TETRA MS 10 dBW, 19 bases, 2017-01-19, 11:16:
- Power dBm
- Uplink
- Tx: TETRA MS 10 dBW
- EIRP: 10,0 dBW
- Tx ant height AGL: 1,5 m
- Rx: Multiple Transmitters
- Prop model: Detvag-90/FOI

■ -99,0 dBm

WRAP 3301 Appendix 2

WRAP 4.18.0.0

Scale: 1:1000000

20 km

Swedish geographical data provided by Lantmäteriet

WRAP International AB
Tanneforsgatan 8
SE-582 24 Linköping
Sweden

Date: 2017-01-19 Page: 1

WRAP
INTERNATIONAL



<p>Result, area</p> <p>Composite, LTE UE -2 dBW, 72 bases, 2017-01-19, 10:54:</p> <p>Power dBm Uplink Tx: LTE UE 10 MHz Vehicle -2dBW EIRP: -2,0 dBW Tx ant height AGL: 1,5 m Rx: Multiple Transmitters Prop model: Detvag-90/FOI</p> <p> -94,0 dBm</p>
<p>WRAP 3301 Appendix 3</p>
<p>WRAP 4.18.0.0</p>
<p>Scale: 1:1000000</p> <p> 20 km</p>
<p><small>Swedish geographical data provided by Lantmäteriet</small></p>
<p>WRAP International AB Tanneforsgatan 8 SE-582 24 Linköping Sweden</p>
<p>Date: 2017-01-19 Page: 1</p>
<p>WRAP <small>INTERNATIONAL</small></p>

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10 Abbreviations

3GPP	Third generation partnership project
BB	Broadband
dB	decibel
ECC	Electronic Communications Committee
FDD	Frequency division duplex
IMS	IP Multimedia Subsystem
IP	Internet Protocol
LTE	Long Term Evolution
MCPTT	Mission critical push to talk
MHz	Megahertz
MVNO	Mobile virtual network operator
NB	Narrowband
OSS	Operation Support System
PPDR	Public protection and disaster relief
SW	Software
TETRA	Terrestrial Trunked Radio
ITU	International Telecommunication Union
W	Watt