Evolution of the Public Safety and Security Mobile Networks

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Abstract: The emergency services which we all take for granted will in future need high speed mobile data transfer to deliver these services to the people who need them. There are, however, numerous obstacles to implementing high speed data functionalities for PSS (Public Safety and Security) organizations; the two main critical factors being the limited available spectrum to deliver these emergency services as well as the challenge of financing the necessary modifications to improve the current system. The study undertaken here seeks an answer to the question of how to meet the future needs of PSS organizations by devising a number of hypothetical scenarios for investigation. The contemporary mainstream technology, TETRA (Terrestrial Trunked Radio), is chosen as the scenario starting point when defining the roadmap of the future solutions. Using the scenario planning method, which is based upon the change forces identified, four future scenarios are defined, the timescale being the next ten year period up until 2022. According to the scenarios defined, alternative strategies for network operators are proposed. The following conclusions have been drawn: (1) emergency services need a dedicated network, the commercial BB (broadband) cellular network is, nevertheless, a feasible solution for non-critical data transmission; (2) the radio spectrum needs to be allocated for WB (wideband) in the <470MHz area and for BB in the <1GHz area; (3) the WB data network (50…200kbit/s) is an economical high speed mobile data solution in rural areas; (4) LTE (Long Term Evolution) technology is a feasible solution for PSS BB mobile communication and; (5) in future, PSS networks will consist of a set of technologies with appropriate coverage and capacity.
Key words: public safety and security networks, PSS, scenario planning, TETRA, TEDS.

The transmission of video, mobile command and control centre functionality and other new communication services, which Public Safety and Security (PSS) organizations (including police, fire and ambulance services) seek to utilize, require a high speed PSS mobile network (TETRA, 2011; BORGONJEN, 2011). Concurrently the services widely available in commercial mobile networks, such as mobile social computing (FEIJOO *et al*., 2009) are creating expectations for the users of the PSS mobile network. Today's Facebook generation of people live in a world where they have a "real time" touch with the surrounding digital world – and they expect nothing less in their daily work. Society aims to guarantee the broadband universal service to every citizen (TEPPAYAYON & BOHLIN, 2010). The volumes have made possible the supply of highly complicated fixed and mobile broadband network products to commercial markets. In the past PSS organizations have been used using superior communication tools compared to the general public. The rapid speed of technological development for consumer handsets has made the technology widely available to all. Now they, the authorities of society, are no longer leading this development. They are following the development and desperately seeking to keep pace with it.

The concepts of the existing PSS mobile networks, i.e. TETRA (Terrestrial Trunked Radio) or TETRAPOL in Europe and APCO P25 in US have been developed two decades ago. The air interfaces of these dedicated systems target a wide coverage with a few base stations; with the narrow bandwidth they offer the group call subscriber service and are able to guarantee good availability. These PSS mobile networks have traditionally had two fundamental requirements: (1) almost 100% availability of service and (2) the security of the communication. The existing implementations are good for voice communication, however, they fail to support new requirements to transmit high speed data services. In the TETRA networks the existing data transmission capacity is based on narrowband (NB) technology, meaning data speeds of 5…20 kbit/s. Specific wideband (WB) technology has been developed for TETRA networks called TEDS (TETRA Enhanced Data System) technology, which will offer data speeds of 50…200 kbit/s. The capacity which PSS organizations would like to have is somewhere in the range of 100…1000 kilobits per second, meaning the use of mobile WB or mobile BB (broadband) or both technologies.

The TETRA technology has suffered from the absence of a powerful ecosystem, something that the cellular solutions have greatly benefitted from. Commercial technologies could be utilized in PSS networks either by taking advantage of the services of commercial networks or by using the same technology used in the commercial operator networks. So far the utilization of cellular technologies by PSS organizations has met with little success; the technologies, such as GSM and UMTS, suffer from technical limitations when implementing the necessary PSS functionality. When using the network services of the commercial operators to deliver emergency services, the poor availability of the service is a fundamental problem in times of serious emergency.

This study answers the question: what is the mobile network solution for PSS organizations in ten years from now? Although not all future applications are well understood, the network service expectations are relatively straightforward – higher mobile data speeds are required (BORGONJEN, 2011). There are many issues, which have a major impact on the high speed mobile network solution which will (most likely) be used in the future. These include spectrum availability (in particular the timing of the availability), financial limitations and their effects on the network structure, high security and availability requirements, technology alternatives as well as the possible role that commercial cellular networks might play in the future delivery of emergency services to people. This current research focuses on the mobile access part of the mobile network. The paper and its results are relevant in countries which already have or are going to have a TETRA system for their emergency communication requirements.

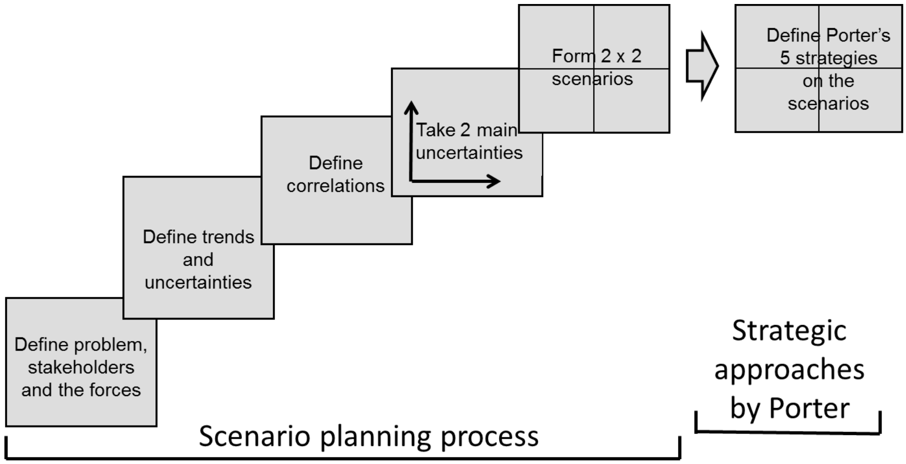
As a starting point, this study adopts the scenario planning method (SCHOEMAKER & MAVADDAT, 2000) and a number of alternative scenarios for future PSS networks are drafted. After the scenarios have been defined, the appropriate operator strategies are selected (PORTER, 1985) for the purpose of finding an optimum techno-economical response to the scenarios. Finally, concluding the optimum strategy and the trends, the roadmap of the network solution for PSS organizations can be defined. This paper builds upon earlier research published by the author (PELTOLA, 2011).

■ Scenario planning method used to find future alternatives

Alternative scenarios of the coming future are defined by using scenario planning (SCHOEMAKER & MAVADDAT, 2000) which does not try to find a single solution, but a limited number of future alternatives. The overall research method is described in figure 1.

This study uses the interviews with the stakeholders of PSS mobile communications to identify the change forces. The interviews are conducted by asking professionals of the telecommunication industry and people involved within public safety communication to give their views of the business forces and of the development of PSS mobile networks. Based on the scoring of the forces, the trends and uncertainties are named. The forces which have high importance and high predictability are called trends. The forces having high importance and low predictability are called uncertainties.

Figure 1 – Research method diagram for the scenario formulation

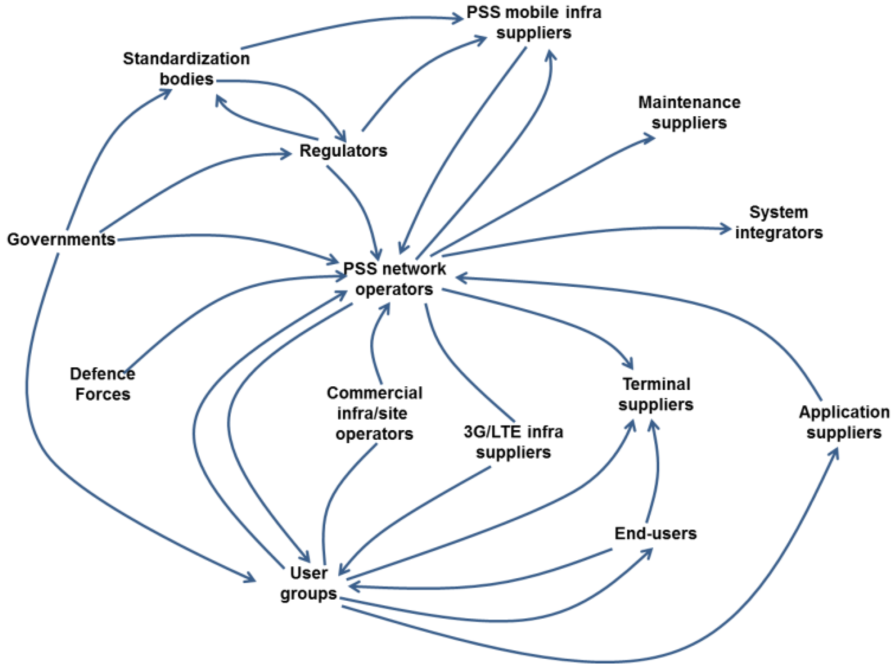


In the following step the correlations between the uncertainties are checked by drawing causalities (STERMAN, 2000) of the main uncertainties to better understand the mutual relationships. Based on the causal loop diagram and the strongest correlations the two most important uncertainties can be selected. Two key uncertainties can be used to form a two-by-two matrix, where each of four cells will be a core of a scenario. The suitable outcomes of other uncertainties and the trends are then added to complete the scenarios. Based on this information the final scenarios are defined and described.

The scenarios are tested using them as input data for the strategy planning according to PORTER (1985). Porter says that "there are five basic approaches to dealing with uncertainty in strategy selection when a firm faces plausible scenarios with differing strategic implications". The five strategy alternatives are: (1) a strategy based on the most probable scenario, (2) a strategy based on the best scenario, (3) a hedge strategy, i.e. protect yourself to be ready for all scenario alternatives, (4) a preserve flexibility strategy, i.e. wait and see what will happen and (5) an influence strategy, i.e. influence the causal factors, which are the basis of the favourable scenario variables. Finally the sixth strategy is developed – it is a combination of the five listed strategies (PORTER, 1985).

Defining trends and uncertainties by interviews

Figure 2 – Stakeholders of the PSS mobile network



The definition of trends and uncertainties is based on the face-to-face interviews. The interviewed people represented stakeholders (figure 2), who have an impact on the development of future PSS mobile networks. Twenty people were interviewed representing all other stakeholders, shown in figure 2, except Defence Forces and Regulators. The interviewed people represented 14 organizations in 6 countries (Belgium, Finland, Hong Kong, the Netherlands, Sweden and UK). The main questions they had to answer were: (1) what are the forces affecting the future development of PSS mobile networks; (2) score the importance of the forces you listed in the scale of (1…5), 5 being the most important and (3) score the predictability of the forces you listed in the scale of (1…5), 5 being the most uncertain.

Table 1 lists the main change forces which were identified during the interviews. The force is named as a trend if its importance is 5 and its predictability at least 3 or if its importance is 4 and its predictability at least 4. The force, whose importance is 5, but the predictability less than 3 is included among the uncertainties.

Table 1 - Forces effecting the development of PSS mobile network

Political forces		
1. Increase of crime and terrorism	5	2
2. Openness in activities of authorities	3	4
3. Availability of additional spectrum	5	1
Economic forces		
4. Budget financing of PSS networks	5	1
5. Development of mobile command and control	5	2
6. Instability of ownership of the commercial networks	4	3
7. Return on Investment (RoI) requirement	4	3
8. Operational costs	4	5
Social forces		
9. Internet generation is driving the use of Internet	3	5
10. Additional vulnerability of society	4	3
11. New emergency organizations	4	4
Technical forces		
12. The technology gap between PSS and 3G networks	5	5
13. The development of new PSS mobile technology	5	1
14. The development of TEDS solutions	5	3
15. Intelligent terminals, with storage capacity	3	3
16. Development of the compression technique	4	4
17. Diversity of networks and terminals	4	4
18. Tighter security requirements	5	1
19. Network traffic load control	3	2
20. Sophisticated communication devices utilized by criminals	4	4
21. Dynamic spectrum access and cognitive radios	5	1
22. Access to local memory storages	3	3
23. Role of memory storage sensors (rfid)	3	1
Industry/Operator forces		
24. The PSS business case of commercial operators	4	4
25. Path dependence of existing PSS networks	4	4
26. Poor reliability of commercial networks	5	4
27. Situation awareness sets new requirements	5	2
28. Fast expansion of 3G networks	4	4
End-user/functionality forces		
29. Expectations based on 3G services/functionalities	5	4
30. Increase of crucial data communication	5	4
31. Operational pressure for new applications	5	1
32. Indoor coverage requirements	3	3

First column = Name of the force affecting the development of PSS mobile network
Second column = Importance of the force (5=high, 1=low)
Third column = Predictability of the force (5=high, 1=low)

■ Constructing scenarios

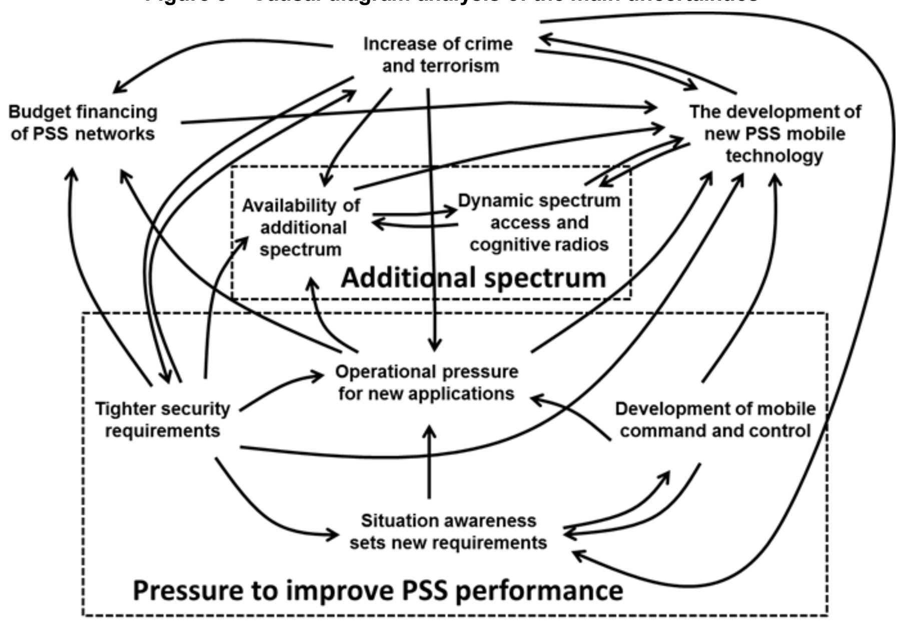
The main uncertainties are listed in table 2, the most important being listed first. The causal loop diagram showing causalities (STERMAN, 2000) between the uncertainties is drawn (figure 3). The selection of the main uncertainties is based on the causal diagram, where candidates are as much as possible nondependent on others and influential. The combined forces

"Additional spectrum" and "Pressure to improve PSS performance" are named as the two main uncertainties when defining future scenarios.

Table 2 - Main uncertainties

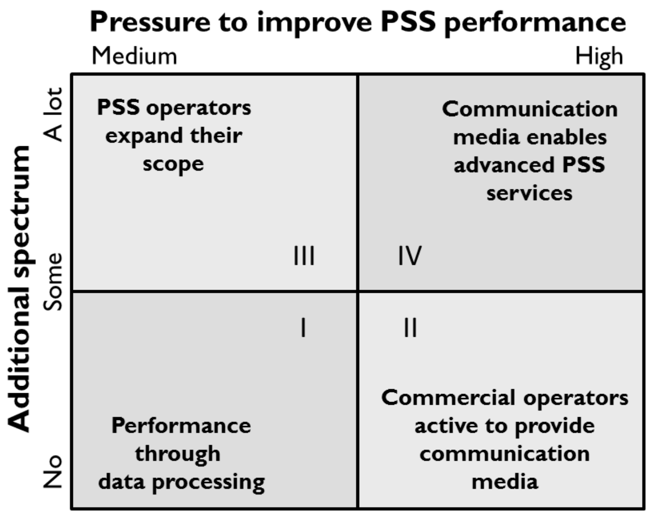
3. Availability of additional spectrum
4. Budget financing of PSS networks
13. The development of new PSS mobile technology
18. Tighter security requirements
31. Operational pressure for new applications
21. Dynamic spectrum access and cognitive radios
1. Increase of crime and terrorism
5. Development of mobile command and control
27. Situation awareness sets new requirements

Figure 3 – Causal diagram analysis of the main uncertainties



Two main uncertainties are the basis for developing four initial scenarios (SCHOEMAKER & MAVADDAT, 2000). In figure 4 the vertical axis "Additional spectrum" is taken to represent spectrum related uncertainties and the horizontal axis "Pressure to improve PSS performance" represents the pressure to take new applications into use. Each of the four quarters represents a specific scenario. It is important to notice, that in every scenario two uncertainties have specific values and all trends are included in all four scenarios.

Figure 4 – Four scenarios in quarters I - IV



Scenario I - Performance through data processing

Scenario I is very much the existing solution, there is no additional spectrum available and there is medium pressure to take new applications into use to improve the performance. The medium performance improvements can be made: (1) by utilizing commercial networks for non-critical communication and (2) by taking into use the TEDS technology, if the existing frequency band allows that and (3) by improving the usage of the communication channels. The latter can be done with better data compression.

Scenario II - Commercial operators active to provide communication media

Scenario II is the case where there is high pressure to take new applications into use; the financing can be arranged, but the additional spectrum is missing. In this case the only solution is to utilize the existing available bandwidth in an optimal way. This is done: (1) by building as much TEDS capacity as possible within the existing bandwidth and; (2) by using commercial BB networks for non-critical high speed data transportation without sacrificing availability and security.

Scenario III - PSS operators expand their scope

In scenario III there is only medium operational pressure to take new applications into use; however, the PSS operator has a lot of spectrum. In this scenario the PSS operators expand their business scope to the commercial customers by offering fixed wireless BB service in rural areas by utilizing the new allocated frequencies. The regulatory authorities allow this, because commercial operators are not interested in the negligible business in rural areas. And the access non-availability risk is minor – because the number of fixed wireless service customers in rural areas is fixed. In this scenario the TEDS network is built in the area which is between suburban and rural areas. As a conclusion the urban and suburban areas, as well as low populated rural areas, are covered by the dedicated BB network. The frequencies are utilized reasonably well, the fixed wireless business supports the investment costs in rural areas and the "commercial" customers belong to the business segment, which is not of interest to the commercial operators.

Scenario IV - Communication media enables advanced PSS services

In scenario IV the high pressure to take new applications into use exists and a lot of additional spectrum has been allocated. Because of the investment optimization the high availability WB network is built covering the whole country excluding the urban and the suburban areas. The dedicated BB network, which can be based on LTE (Long Term Evolution) technology, covers the remaining urban and the suburban areas.

Strategic implications

After the scenarios have been developed, the analysis of the scenarios is performed using PORTER's (1985) approach, where five alternative strategies are developed for the organization involved with the business. In this study the most appropriate stakeholder, for whom the strategy is defined, is the PSS network operator. In the following the Hedge and Preserve Flexibility strategy alternatives are not presented, because they are not real options.

Bet on the most probable scenario

The most probable scenario strategy (figure 5) is a strategy which seems to be an obvious choice based on the common knowledge of the business environment (PORTER, 1985). When referring to the alternatives given by the scenario planning, and taking into account trends and also the time span, the conclusion is the following: there is pressure to take new applications into use, i.e. video and the mobile command and control. The new applications require more data link capacity – and most probably some additional spectrum will finally be allocated for PSS communication usage. However, the allocation of new spectrum is a slow process, and besides the allocation, the time is needed for standardization, product specification, product development and network implementation.

For these reasons the first step must be to meet the additional capacity requirements using only the existing frequency bands, utilizing spectrum more efficiently and using commercial networks where (and whenever) possible. In practice this means better usage of narrowband data transmission, by building 50kHz channel TEDS networks if unallocated frequencies are available – first in urban and suburban areas – and to transfer non-critical communication into the commercial networks. The multichannel routers in the vehicles make possible running the same applications over different networks. The work for starting the roll-out of the dedicated BB network (LTE < 1GHz) after 2015 is a part of this strategy.

Figure 5 – Bet on the most probable scenario strategy

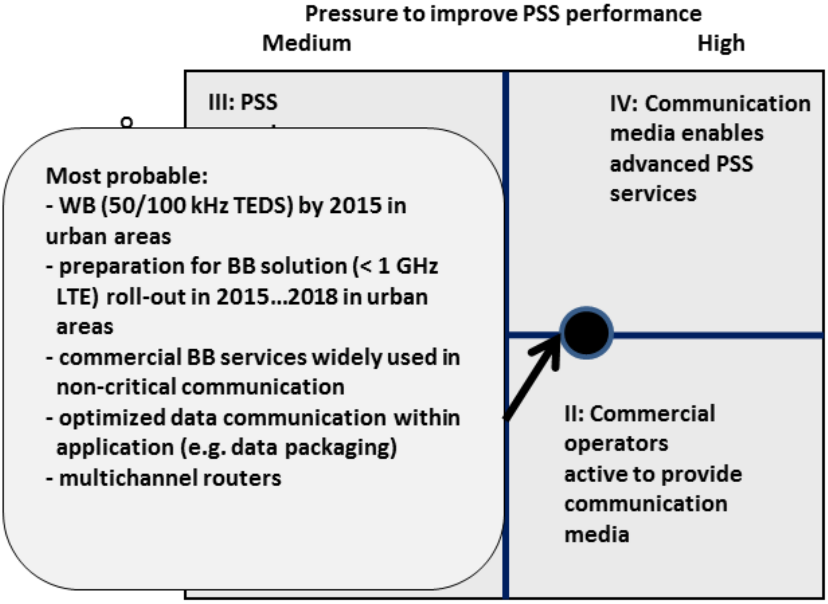
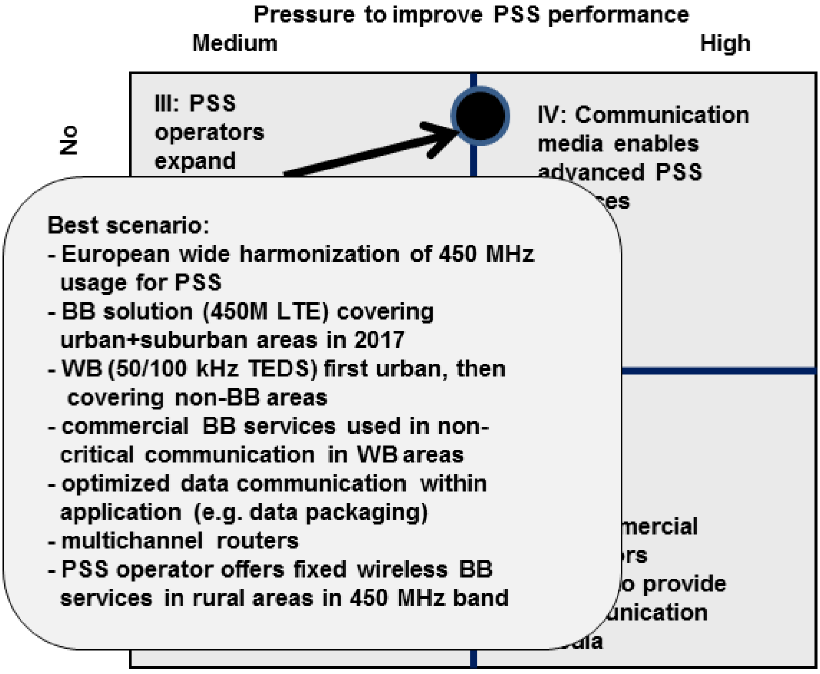


Figure 6 – Bet on the best scenario strategy



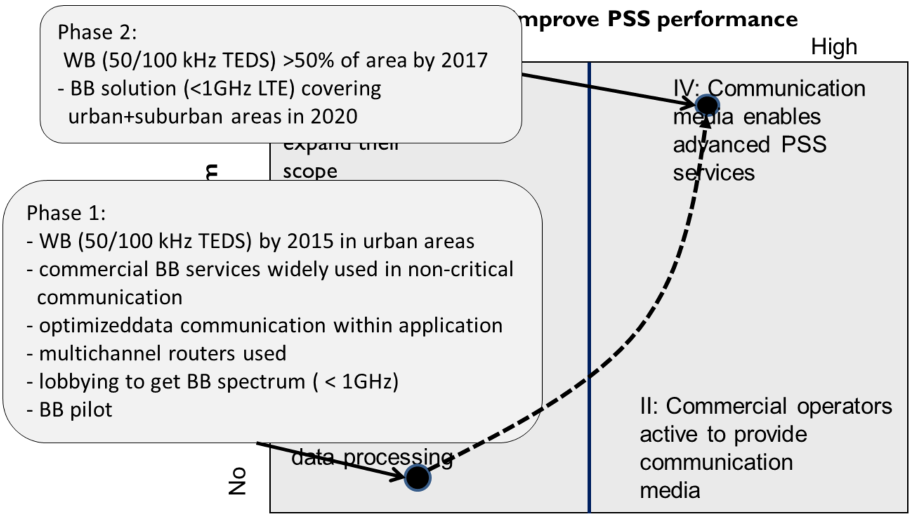
Bet on the best scenario

The Best Scenario strategy is a strategy which is the most favourable to the PSS operator stakeholder in longer term taking into account its resources, competences and the starting point (PORTER, 1985). The Best scenario to the PSS operator is (figure 6), again taking into account the time span and the trends: the additional spectrum is allocated for the operator free of charge in the 400 MHz area and the operational pressure for new applications stays in balance with the capability of the investments for the new network. The additional data capacity will be built first in key urban areas based on the WB/TEDS technology and on the utilization of the existing base station infrastructure. With enhanced data compression technology and additional spectrum allocation for the WB network, the solution selected can carry the present data communication needs, while at the same time the non-critical data communication is transferred to cellular networks. The building of the BB network will be started in the 450 MHz range in 2015, so that the network covers the main part of the country by 2017. The PSS operator will also offer fixed wireless BB services in rural areas in the 450M frequency band. After the roll-out of the BB network, the WB network covers only those rural areas where no fixed wireless coverage exists.

Influence

In the Influence strategy the company uses its resources to push the scenario which seems to be favourable to the company (PORTER, 1985). The desired scenario is that the additional spectrum is allocated for the operator free of charge, the operational pressure for new applications stays in balance with the capability of new network investments and the utilization of the existing network investment can be continued. The Influence strategy will be the following: the spectrum lobbying is focused towards gaining additional bands (1.5 + 1.5 MHz for NB, 3+3 MHz for WB in the 410…430 MHz area and for BB 2 x 10MHz preferably in the area of 400 MHz but at least in the area of <1 GHz.). At the same time the application developers are encouraged to develop solutions which are optimized better with regard to the utilization of the data link capacity.

Figure 7 – Combined based mainly on the most probable and influence strategies



Combined strategy

According to PORTER (1985), "it is often possible and desirable to employ combined and sequential strategies". The Combined strategy is formed by combining elements of the predefined five strategies. In this case the Combined strategy is formed based on the Most probable and Influence strategies (figure 7). The strategy forms a roadmap type of plan, i.e. sequential, moving from scenario I towards scenario IV. In this strategy the present TETRA network infrastructure is utilized as far as it is an economical solution for voice. The WB network will be built for mission critical data based on TEDS technology with 50 kHz channels and will utilize the existing base station infrastructure. Additionally, the commercial cellular networks are utilized for non-critical data communication. The data transmission efficiency will be improved with the use of compression technology and by optimizing data packing in applications. The PSS operators will lobby the regulators to get a harmonized spectrum for WB and BB networks. Later the WB network (100 kHz channels) will be completed based on the NB network base station infrastructure and new allocated frequencies in the <470 MHz frequency band. The BB data network – using LTE technology - is built into urban and suburban areas; the frequency band is 10+10 MHz in the <1 GHz area. The population density will guide the local technology choices and the coverage plans.

Choice of strategy

According to PORTER (1985), "the following factors are most important in choosing a firm's approach: (1) first-mover advantages, (2) initial competitive position, (3) cost or resources required and (4) risk".

In this case it means: (1) to be a first-mover, i.e. to start the BB pilots as soon as possible, otherwise the pressure from users may lead to the uncontrolled (and unsecured) utilization of commercial services and to utilize, in a controlled way, the commercial services for non-mission critical communication; (2) to keep initial competitive position, i.e. to utilize the existing TETRA base station site infrastructure as a competitive advantage – this can be done with TEDS technology; (3) to keep the costs within an acceptable level, i.e. to base the strategy on the roadmap type of approach and to take into account the possibility of implementing the service step by step using the heterogeneous network architecture as well as (4) to understand the threat of the alternatives, i.e. to utilize commercial networks as widely as is possible.

When analysing Porter's strategy criteria and defined strategy alternatives, the combined strategy seems to fulfil best the criteria Porter has stated.

■ Key findings of the study

Needs of high speed data communication

New PSS applications, like video, need higher data link capacity than currently available in TETRA networks (TETRA, 2011; BORGONJEN, 2011); however, the wideband connection (50…200 kbit/s) might be enough for most applications.

Based on the interviews the need of new applications is clear but the necessary financing makes the timetable unclear. That's why the "Pressure to improve PSS performance" was selected as one of two key uncertainty parameters of future PSS mobile network scenarios. Video, if widely used, like with the object tracking software, will need the broadband mobile network for transmission. During the interviews also the mobile command and control was seen as one of those new services which will be crucial in future and will be based on high speed mobile data communication. Some trends were clear: (1) when emergency network users utilize their private cell phones it creates expectations of how PSS mobile communication should work, (2) the gap between the usability of TETRA and UMTS services is remarkable and (3) the difference will be huge when LTE networks are taken into use. This will cause pressure to increase bit rates in the PSS data communication network; otherwise there is a danger that the critical communication will be moved into non-secured commercial networks.

Challenges in utilization of services of commercial mobile networks

The utilization of commercial networks as a PSS network has been one of the toughest questions in all discussions about PSS network evolution. The commercial networks have many advantages: the networks already exist, the coverage is excellent – many networks even cover the same areas, the indoor coverage is good, the data speeds offered by the network are very high, the terminal offering is good, the functionality of the terminals is excellent and the price level of the terminals is low. However, the commercial mobile networks seem to have some fundamental problems if the networks are used for PSS mobile communication – this was seen clearly as a trend in the interviews.

One of the critical problems is that the networks become jammed in disaster situations because a huge amount of subscribers try to reach their closest ones (LAVERY & HORAN, 2005; SWAN & TAYLOR, 2003). One way to resolve the jamming problem has been to grant authorities the higher priority or even prohibit the calls made by ordinary people. If commercial customers would be aware of the priority adjustments during times of emergency, the operator may have problems to acquire users of its network. Another drawback of the usage of priority is that it would lead to overloading of the emergency response centres simply because people would try to call to someone in any case. And if the mobile phone service is completely blocked from the public, then the public cannot give any warnings or alarms.

Together with the jamming problem there is an ongoing debate about the underuse of the spectrum in the public safety and security networks – the full capacity is needed only when an incident happens. Because of this, there are proposals that commercial users would utilize the unused frequencies while the spectrum is not used by PSS agencies. The issue might be that in times of emergency the traffic is increased dramatically by both user groups, by both the commercial as well as the public safety agencies.

The public-private partnership arrangement to share the spectrum and to build the PSS LTE mobile network has been a plan underway in the United States. If the business case can be implemented and the mechanisms are found to guarantee the needed capacity for the emergency agencies in times of disaster, the model may be copied to Europe. Unfortunately, we will never know if it worked in practice because the US plan never came to fruition due to the failure of the auction (FCC, 2011). In any case the LTE technology is capable of sharing the capacity of the same network elements between different operators – this might improve the economics of LTE in PSS solutions. Nonetheless, there remains the fundamental weakness that if the mobile trunk network used is common with the commercial users, then the overloading of this mobile trunk network is possible; this might be true especially if the normal Internet traffic is allowed to be routed through the same IP-trunks as the mobile network uses. The other fundamental problems the commercial networks have are their capability to tolerate only short power supply breaks and to have long repair times. Both mean poor availability. The availability problem might certainly be too expensive to fix in wide cellular networks.

When the commercial operator offers PSS mobile services which are based on the utilization of the commercial mobile network the business case may be challenging. The tight security and availability requirements require additional investments yet the volume of the PSS subscribers is only a few per cent of the total subscriber amount. Also the possible remedy fees may be difficult to define between the authorities and the network operator. The surcharge should be so high that it forces making the necessary investment – however, it should be acceptable from the business case point of view.

The security of the commercial networks is also an issue for the authorities which should not be treated lightly. The ownership changes of the mobile network operator are an unknown security risk. The threat of cyber-attack is a real one, which is difficult to anticipate and eliminate beforehand in commercial networks: these networks have enormous amounts of links to the surrounding environment.

All in all, the utilization of the commercial mobile networks has benefits, but if the service is supplied for the PSS organizations, today there seems to be many fundamental problems in the availability of those networks. The drawbacks seem to be so obvious that "utilization of commercial networks" was not proposed to be one of the two key parameters of the scenario matrix, but "poor reliability of commercial networks" and "the (poor) PSS business case of commercial operators" from table I were seen as trends.

Spectrum availability

The additional spectrum (TETRA, 2011) and financing are both needed to obtain higher bit rates for PSS users in the emergency mobile networks. The availability (or non-availability) of the additional spectrum for PSS mobile networks has a fundamental impact on the future alternatives of the new PSS mobile services and especially on the mobile high speed data services. Based on the interviews and reports (TETRA, 2011), both the timetable and the availability of additional spectrum for PSS mobile remain unclear. Therefore the "Additional spectrum" was named as one of two key uncertainty parameters of future PSS mobile network scenarios.

To keep the number of the base stations low and the additional investments within an acceptable level, it is crucial that the WB frequencies are in the area of 380…470MHz and the BB spectrum in the < 1GHz area. However, the emancipation of the frequencies may take years following the product development time, the time needed for the purchasing decisions as well as the time for implementations. This will highlight the importance of the development of TEDS within the 50 kHz channel bandwidth and the need to improve the applications to minimize data transmission volumes.

Development of mobile technologies for PSS agencies

In the scenario planning analysis the forces based on technology alternatives were identified as trends – the development of PSS mobile technologies looked relative clear within a ten-year timeframe because (1) the PSS mobile technology has to follow the cellular technology to achieve reasonable volume (i.e. cost efficiency) and (2) the deployment of new PSS networks is a rather long process in every country.

TETRA

Some of the newest nationwide TETRA networks will be completely rolled-out in the early 2010s. That means that those networks will most probably be in operational use until the end of 2020s. On the other hand it can be seen that there is no other technology which includes the needed voice functionalities. The main issue in many cellular technologies to replace TETRA is the long latency time, but it seems to be solved in the LTE technology. It will be also important to notice, that when the existing TETRA technology is replaced, a separate spectrum for that replacement is needed – in one form or other.

TEDS

In the best case TEDS can be rolled-out with marginal costs, i.e. only additional radio capacity is needed and the existing TETRA infrastructure can be used (SAIJONMAA, 2009; Motorola, 2009). In a few countries the needed free spectrum exists for a 50 kHz channel system, which makes quick implementation possible. The role of the TEDS technology will be a medium term mobile WB data solution in urban areas – until the BB solution exists – and a long term solution in rural areas. If the described roadmap is realized, then TEDS' volumes will stay low and only the vehicle models of TEDS terminals will be available from the terminal suppliers.

Mobile WiMAX

The lack of volumes in terminal markets has been one of the key problems that the entire TETRA ecosystem has suffered from during its lifetime. Therefore the technology of the PSS mobile wideband/broadband has to be based on a leading cellular technology, so that the scale of economies can be achieved. Mobile WiMAX seems to have no technology advantages compared to, for instance, LTE technology, and also WiMAX has not reached any remarkable position in the mobile markets, so the chance of its becoming the leading PSS mobile broadband technology is very slight.

Cognitive radio

The dynamic spectrum access and cognitive radio technologies are based on the technology where the frequency band allocated to party A is utilized by the party B when temporarily the frequency band is not used by party A, which is not at that moment in use, will dynamically be taken into use as long as the said frequencies are unallocated. The issue in the cognitive radio systems is that in cases of emergency all kinds of mobile communication traffic will increase dramatically and the needs for frequencies will increase still further. It therefore appears that this technology would also need certain priority functionalities - with the possible problems that lie within. Another issue is the timing – in a ten-year timeframe – as defined in this paper. The clear target of the new PSS mobile network is also that new PSS mobile technology will enjoy the benefits that the strong ecosystem will bring. The development of cognitive radio technology is still very much in its infancy and is far from what it needs to become.

LTE technology

The LTE technology will be used in the United States to build the BB mobile data network for the emergency services (FCC, 2011). The spectrum band allocated for the service is in the 700 MHz area. The voice communication will be kept in the APCO P25-technology networks (McEWEN, 2009). The benefit that the LTE alternative has is that the selected mobile data technology would be the same technology that will be widely used in commercial networks. This also would mean that the terminal offering is versatile and the price level stays low. The US solution as a role model may mean that the PSS BB mobile solutions will be copied to Europe. The LTE technology is also a potential candidate for the future PSS voice communication solution because its short latency time means that it can fulfil the PSS voice communication call set-up time requirements.

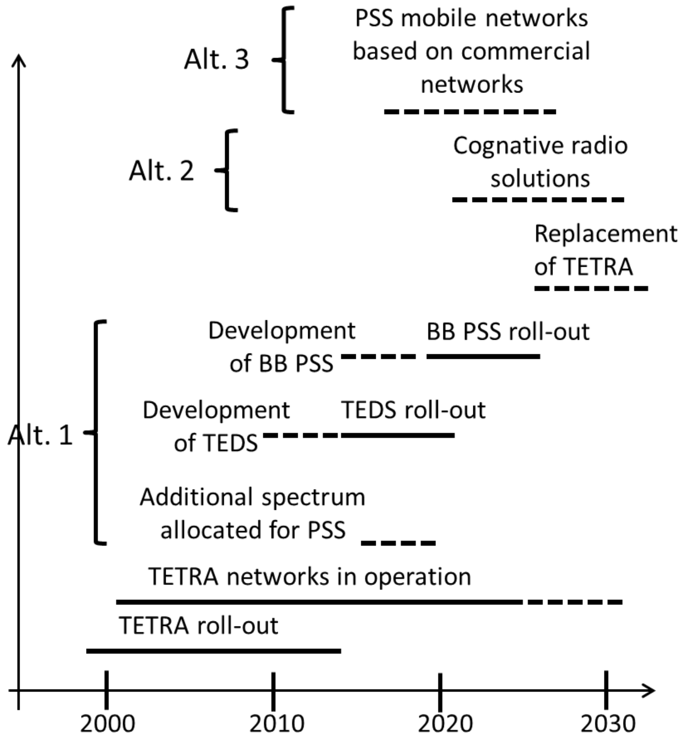
Timing considerations

Figure 8 represents the timing of the possible PSS mobile network alternatives. The development of TETRA started in the early 1990s. The first roll-outs were done at the end of the 1990s and it still continues in many European countries - some of the biggest ongoing roll-outs are the networks in Germany and Norway. The lifetime of TETRA systems can be thought to last until the end of the 2020s – i.e. the TETRA networks may be up and running in many countries until the years 2025…2030.

One of the high speed data alternatives is the utilization of TEDS technology and the new PSS specific BB solution (Alt. 1 in figure 7); this will require additional spectrum. The additional spectrum for PSS mobile communication will be possible to get in Europe sometime between 2015 and 2020, meaning that at that time it will be possible to roll-out PSS specific BB mobile networks. The TEDS technology can be partly rolled-out earlier because some countries have extra spectrum capacity available in the frequencies allocated for TETRA. The development of the 700 MHz band LTE technology for PSS purposes in the United States may have an impact on the future PSS BB technology selections in Europe. If there are no direct frequency allocations, one alternative is the cognitive radio solutions (Alt. 2), which may be available in the 2020s.

The utilization of the commercial mobile networks (Alt. 3) as a media for PSS mobile communication is possible already today. However, based on this study the possibilities of the usage of those networks as a mission critical communication media are seen as weak – because of the poor availability, only the non-critical communication is considered possible.

Figure 8 – Evolution timing consideration

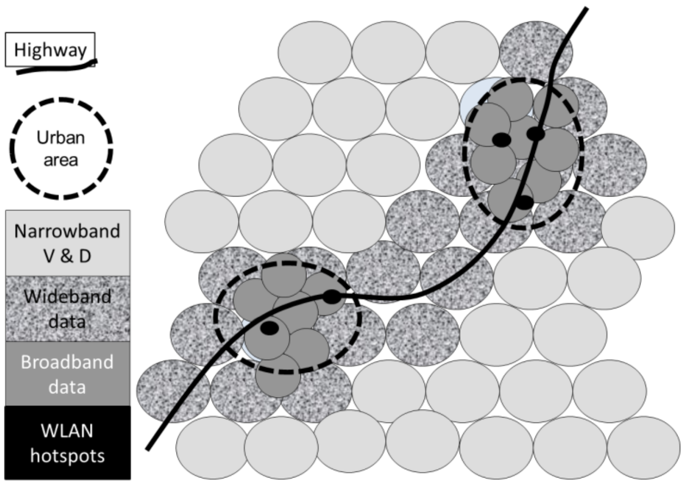


Network architecture - hybrid solution

Based on this study, the PSS mobile communication networks may consist in the future of a set of technologies, i.e. narrowband (TETRA), wideband (TEDS), broadband (LTE) and local area (WLAN) – with appropriate coverage and capacity. The wireless landscape will be more heterogeneous than earlier (LEHR & PUPILLO, 2009). The multi technology solution – a hybrid solution – would give an optimum price per value ratio (figure 9). The following conclusions are made from the network architecture's point of view: (1) the NB mission critical networks, dedicated for voice group calls, have a role as a highly secured voice and low bit rate communication media – until they come to the end of their lifetime; (2) wideband data network – implemented using the TEDS technology and based on the utilization of frequencies next to the TETRA spectrum band –

is an economical solution (SAIJONMAA, 2009; Motorola, 2009) because the same base station sites, what the narrowband network uses, can be utilized. The wideband network fulfils the tough availability requirements, it also fulfils data transmission needs in the medium term, and the development of the compression technology will improve its position; (3) the commercial broadband cellular network can be used and it is sensible to use for non-critical data transmission; (4) as soon as the spectrum has been allocated for BB data network in the <1GHz area, the mission critical broadband data networks can be built based on commercial technologies (e.g. LTE) and (5) e.g. WLAN technology can be utilized locally for database download services and for building ad-hoc networks.

Figure 9 – Economical coverage with heterogeneous networks (ITTNER, 2006)



■ Conclusion

The purpose of the research was to study what form the PSS mobile communication solution will take ten years from now. The chosen method is the scenario planning method (SCHOEMAKER & MAVADDAT, 2000), supported by the strategy review (PORTER, 1985), which consolidates the scenario results. The interviews in the beginning of the research give essential input data for the study. The definition of strategies adds understanding of alternative cases and improves the credibility of the identified scenarios.

The narrowband PSS mobile solution exists and will stay in the short and medium term (McEwen, 2009); the recently built TETRA networks are able to fulfil both voice and slow data communication needs very well. On the other hand, the specific voice functionality is quite complicated to implement with any future system – therefore the focus of the new PSS networks is on high speed mobile data networks.

The need for better mobile communication for PSS organizations is obvious (BORGONJEN, 2011; TETRA, 2011), but the timetable depends on the available spectrum, the pressure of needs and available financing. Surprisingly, in some way the issue of the evolution of PSS mobile network is not the technology – in a ten-year timeframe – because suitable technologies already exist and because PSS mobile networks are more followers of technological development rather than the pioneers of such development. The LTE technology seems to be the best candidate for the technology – it will be a volume technology, it will have a strong position in American PSS markets and also because it is capable of serving as a platform for the voice communication of the emergency organizations.

The key questions that remain are: (1) if and when the authorities allocate more frequencies to the PSS organizations, (2) when will there be real pressure to improve the performance of PSS organizations – taking into account the increased crime and terrorism, (3) can commercial operators improve the availability of their mobile networks so much in order to fulfil the requirements of the PSS organizations – or at least how widely can commercial networks be utilized for non-critical communication and (4) how can the heterogeneous PSS network be built so that the techno-economical optimum can be achieved from society's point of view.

The main obstacle obtaining a secured mobile BB network for PSS agencies is the lack of available spectrum, which the authorities should allocate as soon as possible. The proposal of the needed frequencies has been done for the European Union (TETRA, 2011) asking 2 x 3MHz for mobile wideband in the 410…430MHz area and 2 x 10MHz for mobile broadband in the 700MHz area. However, the earliest time when the asked spectrum allocation decisions can be made is somewhere from three to five years in the future.

The "killer application", which would utilize mobile broadband service is still unclear, however the real need to have mobile broadband clearly exists. The needs for mobile command and control service have been recognized –

also if video will be widely used, for example, together with the object-tracking video software, then the mobile broadband network is needed.

One of the results of the study is that the availability and reliability of the commercial networks are simply not acceptable for mission critical communication, so the PSS organizations have to have their own dedicated WB/BB network – at least in the urban areas.

As with all cellular networks the PSS network service may vary from area to area. The implementation of the future PSS mobile network with the heterogeneous network architecture – with various technologies and offering different data speeds – is a feasible solution from society's point of view to offer BB services for PSS organizations.

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