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Executive Summary

Expert Report on the Qualification of the Vodafone D2 GSM Mobile Phone Network augmented by ASCI¹ and additional functions for the provision of services for the Digital Radio Network for Authorities and Organisations with Safety Responsibilities (BOS)

The expert has

1. collaborated in the specification of the digital phone network for the pilot trial in Aachen [5], conducted numerous discussions with members of BOS project groups and manufacturers of BOS system technology and is entrusted to date with the scientific supervision of the pilot trial in Aachen by the Central Police Technical Services (ZPD), North Rhine-Westphalia.
2. on behalf of the ZPD NRW, studied the qualification of systems conforming to the ETSI Standard TETRA and to the TetraPOL Publicly Available Specification for fulfilment of the specifications for BOS networks in accordance with the Schengen Agreement and determined the number of base stations required for a network throughout Germany [8].
3. on the basis of a complete implementation of the radio interface of TETRA, by means of simulative traffic performance analysis of communication traffic in group communication, studied the traffic capacity and service quality of TETRA in normal and high load cases.
4. demonstrated his comprehensive knowledge of the systems TETRA, GSM incl. ASCI services and GPRS by publishing an extensive textbook [1].
5. drawn on the currently relevant literature and recently published studies and/or expert reports [2, 3, 4, 8, 9] for the qualification of the GSM System for the fulfilment of BOS requirements in the following assessment.

This experience and knowledge provides the basis for the statements in this report which explains in detail and substantiates the extent to which the minimum requirements formulated in the "Final report of the federal and state expert group" (GAN) [4] can be fulfilled by GSM-BOS. GSM-BOS is defined as the Vodafone D2 Mobile Phone Network according to GSM Standard, augmented by ASCI and other additional functions.

The most important advantages of GSM-BOS versus a separate BOS digital radio network are listed at the end of this Executive Summary.

It is noteworthy that, in normal operation, the communication traffic volume of BOS, as established by measurements in the Aachen pilot trial, is small - with high peaks of traffic load in rare high load cases (disaster case). The number of channels required for the handling of the traffic volume is essentially determined by the number of simultaneously active groups and only to a small degree by the number of members in the groups.

¹ Advanced Speech Call Items, ETSI-GSM Standard

For cost reasons (according to the requirements in [4]), a digital radio network is to be realised for normal operation with certain small reserves for increased traffic. In disaster cases, the capacity would then regularly be extremely inadequate, which represents the situation to date in the analogue radio network and would be highly unsatisfactory but unavoidable.

The installation of a separate digital radio network for the BOS can only be justified if there is no other possibility of meeting the BOS requirements at least as well or better.

The essential conclusion of this report is that the functions demanded in [4] and [5], relating, firstly, to urban and rural radio accessibility and the realised communication traffic capacity and, secondly, to the services rendered by means of software, can be realised without restriction or have already been implemented by GSM-BOS, whereby the fulfilment of some of the BOS demands is by far exceeded.

In an assessment of the availability of the services demanded by the BOS from a digital radio network, it must be borne in mind that these are based solely on software which can run on any radio technology. Therefore, there is in principle no reason to assume that a TETRA platform is better qualified than a GSM platform for the provision of BOS services, especially as the transmission rates of GSM radio channels are considerably greater than those of TETRA channels.

In addition to the BOS services, the radio coverage achievable with a radio platform is a particularly important criterion because it characterises the constant availability of the subscriber by the control centre or of the control centre and the fixed network by the mobile subscriber, as are the availability of modern voice and data services, its future compatibility (with adaptation to the latest state of the art) and the paging services. Because of the lower attenuation of radio wave propagation, a platform which transmits at 400 MHz (instead of 900 MHz) has certain advantages which result in a somewhat smaller number of base stations for a specific radio coverage.

In the present case, the expense for the establishment of and the anticipated provision of radio coverage for a digital radio system transmitting at 400 MHz is to be compared with that for an existing system transmitting at 900 MHz:

For reasons of the traffic capacity required for public mobile radio and its high aspiration to in-house coverage, the Vodafone D2 platform, with its 37,000 radio cells, provides such an area density that, location related, there is a radio coverage of 95.5 %. This leads to a very good in-house coverage which, in particular, can also ensure the functionality of a paging system.

In contrast, the 400 MHz system first has to be established and, taking account of the considerable reduction of requirements, for cost reasons according to [4], from earlier demands [5] to only 3,000 base stations, would fail by far to achieve a radio coverage comparable with the Vodafone network.

(In [5], a coverage probability of 95%, with full mobile phone coverage outside buildings, was demanded. In [4], the coverage probability is no longer specified, but there is a demand, for the final phase, for "full vehicle coverage and mobile phone coverage with at least the same coverage as in today's analogue radio", which, according to [4, page 52], "is provided only partially and to a small extent in the quality generally required". This reduced requirement lowers the costs considerably. It renders any satisfactory paging system impossible, so that this will require a separate network.

For a "first step", an even lower, so-called "minimum standard" is aimed at in [4], in which "full radio coverage of urban and traffic areas for mobile phone devices" (11.8% of the area of Germany) and vehicle radio coverage in the remaining area are required. The "reliable lid on costs" of 3.06 billion Euro, described as the absolute upper limit, calculated for a TETRA network in [4, page 68], applies to this highly unsatisfactory minimum standard. Because of the high costs anticipated (which experience suggests will be greater than expected), it may be assumed that, for some Federal States, the "first step" will also be the last.

The time saved by the use of an already largely complete Vodafone D2 infrastructure and the associated cost savings will only be mentioned here as a side note. All concerned are unanimous that GSM-BOS could be realised with complete coverage and reliability in a very much shorter time and at very much lower cost, with only short periods or none at all of simultaneous operation of the existing analogue system and the new network. In contrast, the establishment of a national radio network to TETRA or TetraPOL standard would involve high financial risks and probable long delays. The public resistance to be expected against the installation of the many (according to plans, relatively high) antenna masts and the resulting risks for the time schedule have not even been taken into account here.

Questionable arguments are used in [4, page 37] to make the case that the BOS requires an independent digital radio network for the fulfilment of its responsibilities – and it is consciously accepted that, for cost reasons, this network will have an extremely unsatisfactory radio coverage, under which BOS staff will later suffer and with which the strategic/tactical objectives of the BOS are not realisable because, in many locations, the network will simply not be accessible.

These arguments do not take into account the fact that parts of the fixed networks used today by the BOS are already realised in the form of virtual private networks with transmission and switching technology rented from public network operators. A comparable concept, namely an arrangement of transmission and switching technology, is open to discussion in the form of GSM-BOS.

Many BOS specialists are still uncertain whether GSM-BOS fulfils the required performance specifications and can provide all the important services specified by the BOS. The main part of this report contains detailed statements on this subject and recommends, instead of the phased establishment of a platform according to the TETRA or TetraPOL standard, to make use of the existing Vodafone D2 platform, supplemented with additional ASCI and other BOS functions for the digital radio network of the BOS, because it can completely fulfil all the essential requirements.

An independent BOS digital radio network (e.g. on the basis of TETRA), like its predecessor analogue radio network, would be in operation for over 20 years and, in relation to progress in the state of the art in digital mobile radio, would be obsolete in five to ten years or would require considerable running update investments not currently included in the cost calculation [4].

It must also be borne in mind that the TETRA standard roughly corresponds with GSM technology, the state of the art of the early/mid nineties (even if the technology is only being implemented today). Considerable further developments have meanwhile been made in the GSM technology and the existing Vodafone D2 network now features improvements such as frequency hopping techniques, adaptive modulation and packet data transmission. So these features, which are at present not available in TETRA and which, according to plan, are not to be phased into the TETRA standardisation until later, are already conceivable today.

GSM-BOS also has the advantages that, because of the mass market for GSM voice and data services, all services and functions are constantly maintained at the latest state of the art, guaranteeing the BOS (as a relatively small user group for this technology) updates to the current state of the art without any effort on their own behalf. This applies to all point-to-point voice and data services, the transmission technology for group communication

services and measures for capacity increase by the simultaneous transmission of multiple connections over the same radio channel (MIMO²) and the interface to modern mobile radio networks with other technologies, such as UMTS and WLAN.

A further example of the future capability of the Vodafone D2 platform worthy of mention here is the future planning for ETSI-TETRA "Phase 2 Services" ("TETRA Advanced Packet Services (TAPS)"): TAPS standardises the services known in GSM as General Packet Radio Service (GPRS) for a one-to-one implementation on the TETRA radio platform. These services have not only been developed and standardised in GSM, but are already available and in use as a mass service in Vodafone D2. With the introduction of a digital radio network on the basis of GSM-BOS, the BOS would simultaneously ensure inexpensive access to the future TETRA data services (TAPS) without themselves making any investments in the infrastructure: If required, GPRS would already be available to the BOS from the Vodafone D2 platform and could be used in the terminals from the start. The alternative would be, first, to establish a TETRA Release 1 digital radio network and, later, to acquire the additional infrastructure required for TAPS and the associated terminals.

The expert is aware from numerous discussions with BOS representatives, that packet data transmission is already regarded today as a very important service for the BOS, even if it does not appear among the minimum requirements in [4].

Only one technical parameter value is mentioned by the GAN in [4] which appears at present not to be completely achieved by a Vodafone D2 platform: The time taken, according to measurements, for the set-up of a new connection for a group on a GSM/ASCI platform is < 2 sec in 95% of all cases with Fast Call Set-Up or < 2.5 sec with Normal Call Set-Up, instead of the mean duration of 0.5 sec specified for the digital radio network of the BOS. See the extensive analyses in [9].

It should be pointed out that the new set-up of a group call is an event which occurs infrequently because, after set-up of a connection, a group remains active for a prolonged period, while, in the case of GSM-BOS, each group member can speak at any time (at latest after 0.5 sec).

In order to make the waiting time for the availability of a new group connection occur less frequently, a group call can, if necessary, be held open in GSM-BOS, even when no subscriber has been active for a long period, so that the resumption of the group call is possible with practically no delay (in < 0.5 sec).

It has also been shown in [1] and [8] that, for digital radio networks to TETRA or TetraPOL specification, the set-up of a new connection for a group in the case of high communication traffic volume, even if all group members are in the same cell, takes a mean of 1 - 2 sec and < 4.5 sec in 95% of all cases.

The expert anticipates, with a probability verging on certainty, that when the group is extended outside the area of one base station control, and even more so when more than one switching centre is involved, the set-up of a connection for a group call in the TETRA network, even in the case of low traffic volume, will take just as long as in GSM-BOS, so that there is practically no difference between the systems in this respect. This estimate of the length of waiting time for the set-up of a group connection is confirmed from the

² Multiple In, Multiple Out

operational activity of an existing large TETRA network, in which "something like 0.5 – 2.2 sec on average and 95% confidence limits up to 5 sec" have been observed.

Thus, the only parameter which appears to be more favourable to a TETRA solution as opposed to GSM-BOS (the short time for the set-up of group connections) proves, on closer inspection, to be unsuitable for a differentiation of the systems.

In the view of the expert, even if a TETRA system permitted a slightly faster connection set-up for group calls, the Vodafone D2 platform would still be preferable:

In comparison with the establishment of a new digital radio network for the BOS according to TETRA standard, that (as shown above) would permit no connection set-up at all for mobile handsets at many locations in Germany (or would locally separate group members from their group) because of its inadequate radio coverage, the universally available Vodafone D2 network appears to the expert to be much the better solution, since it permits handset connection set-up for groups almost everywhere and does not separate mobile phone handsets from their group.

It must also be assumed that, upon the introduction of the BSI compliant authentication of group members, the values quoted above for the set-up of a group call will be prolonged by several seconds, independent of the radio technology used, i.e. both for TETRA and for GSM-BOS networks.

In ongoing discussions, the possibility is sometimes raised of using the direct mode for connection with the emergency vehicle in the case of inadequate mobile handset coverage in order to incorporate mobile handsets into the communications. It should be noted here that a mobile handset communicating in direct mode cannot be received by all group members and that the few frequencies reserved for the direct mode do not permit any traffic volume worth mentioning, so that the incorporation of the direct mode is no alternative to proper radio coverage.

It should be mentioned that, on introduction of the Vodafone solution at 380 MHz, 3 MHz (= 120 channels) would be available for the direct mode, whereby a foreseeable bottleneck in a future digital radio network for the BOS would be elegantly eliminated.

The important performance features of a digital radio network for the BOS according to [4, 5, 6] are briefly compared below with the possibilities of GSM-BOS. The complete report contains a detailed comparison.

- A. Radio coverage for voice and data transmission: The coverage demanded in [4] for the final configuration is greatly over-fulfilled by the Vodafone D2 platform: There is mobile handset coverage in-house and in tunnels almost everywhere in Germany. The qualification of GSM for very fast moving objects (high speed trains and aircrafts) has been proven in practice.
- B. Cell change/Operations in motion: GSM-BOS permits the flexibility demanded by the BOS through the manual definition of freely structured Group Areas and the dynamic inclusion of defined cells in which group members are present, the almost uninterrupted (< 0,5 sec) availability of group communications services and connection with the control centre for subscribers on the move, even in the case of a change of the radio cell concerned and the presence of group members in multiple radio cells. In this case, for the respective groups, only those cells are covered in which a subscriber is actually present. A function could be implemented through which the radio cells surrounding the occupied cells would also be covered.

- C. Capacity: GSM-BOS permanently provides the BOS with the required 15 radio channels per base station in urban and 7 in rural areas and, when required, through dynamic switching to half-rate voice codecs³, also permits doubling of the number of channels available. The ASCI function "enhanced Multi-level Precedence and Pre-emption Service, (eMLPP)" also permits (by displacement/interruption of subscribers to the public GSM mobile phone network) the dynamic provision of appreciable additional capacity in the case of a disaster, e.g. a further doubling of the number of traffic channels. Finally, by the dynamic downsizing of the cell concerned (controlled by the network management) and, by installing further transceivers into prepared slots in the base stations concerned (16 channels per transceiver), the capacity can again be greatly increased in a short time. The existing GSM network management has been perfected and permits capacity controls and capacity enlargement for BOS services in every cell at all times and continuously.

A solution is thus available which, without the time-consuming relocation of mobile base stations, can practically immediately provide the locally required capacity in the case of a disaster. Mobile base stations for the Vodafone D2 platform are also exclusively available for BOS. Further mobile base stations are available for maintenance of the public mobile phone network in the case of a disaster or of plannable events.

The provision of very considerable capacity reserves in each cell with the Vodafone D2 platform in the case of a disaster is of very special interest for the BOS (even if this aspect plays no role in the specifications [4]) and, for cost reasons, could never be achieved with a digital radio network specifically realised for the BOS. For this reason alone, a TETRA or TetraPOL based solution, which could never provide the necessary capacity reserves in such disaster cases because of the costs involved, is out of the question for the BOS.

- D. Voice quality: A 100% sentence understanding and/or 96% syllable understanding is only achieved with very good radio coverage which can best be provided on a Vodafone D2 platform. These objectives, formulated as minimum requirements in [4], taking into account the objectives formulated in [4] for radio coverage, are only expected to be met for mobile handsets in about 12% of the area of the FRG, but are fulfillable for mobile handsets practically throughout the country with the Vodafone D2 platform.
- E. Pre-emptive rights: Thanks to the availability of the eMLPP service, see C., all BOS requirements can be completely fulfilled.
- F. Connection of control centres: GSM-BOS uses so-called Connectivity Servers to permit the system-wide connection of control centres (also from outside the Group Call Area) over standardised interfaces. In interaction with the GSM components Home Location Register, Visited Location Register, Authentication Centre, Network Management etc., the control centre can fulfil all the requirements defined in [4], including the security functions, allocation/definition of rights, administration of operative/tactical addresses, priority control, remote parameterisation of terminals, dynamic group formation, definition of the coverage area for groups, surveillance/connection controls for individual subscribers, data connections, alarm and clear text display, documentation, dynamic connection of additional control centres etc.
- G. Security/Availability of equipment and network: Is fulfilled.

³ The voice comprehensibility of half-rate voice codecs is assessed as equal to that of full-rate voice codecs.

- H. Address space: In addition to fulfilment of the BOS requirements, it is worth mentioning that dynamic change of group membership over the radio interface from the (authorised) control centre is offered in GSM-BOS. For this purpose, functions of the GSM Subscriber Identity Module (SIM), in combination with the SIM Application Toolkit and a new additional function, "Over-the-Air Configuration", of group membership are used.
- I. Operative-tactical addresses: The required functions can be realised.
- J. Group communication: All service features required by the BOS are fulfilled.
- K. Individual communication: GSM-BOS provides self-dialling as standard for full-duplex voice connections between mobile subscribers and with subscribers in the fixed network or in the control centre. Thus, more comfortable communication is possible than with the alternating simplex (semi-duplex) specified in accordance with the BOS requirements [4] for the connection between mobile subscribers.
- L. Emergency call: GSM-BOS includes the emergency call function of the GSM standard, which is oriented on an installation corresponding to a control centre and provides for a connection set-up in 1 - 2 sec (Group Emergency Application).
- M. Encryption: The signalling and user data of the GSM radio interface are transmitted encrypted as standard; unencrypted transmission is possible. The encryption concept of the BSI, based on the functions of the GSM-SIM, is easily integrated.
- N. Data transmission: Because of its lower frequency channel width of 25 kHz, the TETRA system will never achieve the data transmission rate (of up to 53.6 kbit/s) which is today available on the Vodafone D2 platform with its standard 200 kHz bandwidth. Data transmission today already runs in parallel with voice transmission (e.g. SMS, short data transmission in voice pauses). The TETRA Advanced Packet Service (TAPS) specified for TETRA Systems, which corresponds exactly with the GPRS service, is already available on the Vodafone D2 platform. If, on the other hand, a TETRA solution were acquired, this would have to be introduced later for reasons of unavailability (at the earliest, in 5 years), would require considerable additional investment in infrastructure and the replacement of many BOS terminals, leading to appreciable additional costs which are not taken into account in [4].
- O. Paging system: GSM-BOS will in addition to the four existing SMS Service Centres provide and reserve another SMS-C exclusively for the BOS and, in this way, achieve the required conditions for the paging system. The GSM Short Message Service (SMS) realises an automatically acknowledged alarm. An active acknowledgement by the subscriber is possible by sending a prepared SMS message. A passive alarm is realised by the use of standard GSM terminals with a suppressed transmission function and Cell Broadcast. The terminal with suppressed transmission function is the same size as the small GSM terminals required for passive pagers. The suitability of the SMS services for the alarming of helpers for dyke watching (with time and volume demands comparable with the BOS) may be regarded as confirmed after years of operation. The paging functionality by GSM/SMS corresponds with the paging service of TETRA using SDS (short data service), whereby, because of its significantly better urban and rural building coverage, the accessibility of subscribers with the Vodafone D2 GSM platform will be much better than it could ever be with a TETRA network according to [4, 5].
- P. Transitions into other radio networks with the same system technology: GSM radio networks can interoperate with any other radio network and fixed network. The right of communication with subscribers of another radio network is dynamically granted by GSM-BOS from a control centre.
In the case of the same technology on both sides of a national border (the normal

case for GSM networks), all BOS requirements can be fulfilled.

In the case of different technology on either side of a national border, all BOS requirements can be fulfilled. If required, in the case of GSM-BOS, mobile terminals for the BOS can be so designed that they are also fully functional in a TETRA radio network on the other side of the border, since they already possess the 400 MHz TETRA radio interface for realisation of the direct mode. That means that the mobile terminals planned for GSM-BOS are dual-mode terminals which can communicate with both GSM-BOS and TETRA base stations in neighbouring countries.

- Q. Transition to public telephone networks and telecommunications systems: All required functions are already available today.
- R. Linkage with data networks: All functions required by the BOS are already fulfilled today.
- S. Linkage of the analogue with the future digital system: The transition to the future digital system would be possible in a very short time in the case of the introduction of GSM-BOS. The costs for elaborate transitional solutions until the 100 % establishment of the digital network could be minimised. Accordingly, the decision for GSM-BOS as the future digital radio network of the BOS appears particularly attractive.

The minimum requirements [4] do not specify direct mode operation between mobile handsets and between hand and vehicle terminals with dual-watch and repeater function as contained in [5]. The GSM-BOS direct mode operation is realised in the terminals in the form of the original TETRA radio interface in the 400 MHz band – with all resultant advantages, such as the avoidance of interference with the normal communication mode in the 900 MHz band, the use of additional available frequencies (a total of 120 channels) for the direct mode and high penetration depth inside massive buildings such as underground car parks etc.

The statements of this report are based on the above basis 1 to 5, the published ETSI-GSM/ASCI and ETSI/TETRA standards and consideration of the additional functions specified for GSM-BOS.

The expert strongly recommends testing the current status of the implementation of GSM-BOS and its qualification for the BOS in a limited period pilot trial. In the course of this trial, the essential additional functions offered for the BOS by Vodafone D2, insofar as already available, can also be tested and included in a concluding evaluation.

Summary of the report

GSM-BOS has the following advantages over a digital radio network established according to the specifications of the GAN [4] on the basis of another standard:

- I) The radio network would be available and usable throughout the entire area within approx. 2 years after award of the contract.
- II) The radio coverage for mobile handsets and alarm calls would be achieved over a unified network and would be appreciably better (from a cost point of view) than that planned by the BOS according to [4]. The security of BOS personnel would be dramatically improved by their constant accessibility in emergency situations.

- III) The alarm calling of paging receivers would be finally resolved to the satisfaction of all concerned.
- IV) The costs for the parallel operation of the existing analogue radio network in the introductory phase of the successor network could be minimised because the successor system is already in place over the whole area.
- V) In every cell, by means of switching to half-rate voice operation, displacement of public mobile phone traffic, dynamic downsizing of the cell and other measures, there is an immediately usable capacity reserve of three or four times the regular size, sufficient to carry traffic in the case of a disaster.
- VI) All technical requirements of the BOS would be fulfilled and many requirements would be greatly over-fulfilled.
- VII) The problem of the acquisition of new sites for base stations in populated areas is eliminated.
- VIII) The acquisition and operating costs would be much lower. The additional costs for the acquisition of a separate digital radio network for the BOS, which would have a distinctly worse radio coverage and no adequate capacity reserves, would be hard to explain to the public.
- IX) Because of the wide overlap of the coverage areas of the existing Vodafone base stations, availability would still be ensured even if a cell failed.
- X) The direct mode operation between terminals ("Walkie Talkie") is available in the form of the TETRA standard compliant solution, but the feared interference of the direct mode with the base station mode in the case of a digital radio network according to TETRA standard is eliminated. There would be 120 channels available for the direct mode alone.
- XI) For use in neighbouring countries, both TETRA and GSM radio interfaces are available in the mobile terminals.
- XII) The constant updating of the radio technology to the state of the art would be undertaken by the operator (for its public mobile phone customers). The BOS would be the beneficiary – no infrastructure costs are incurred by the BOS.
- XIII) The GPRS packet data service ("TETRA Phase 2") is available from the start. The data transmission rates would correspond with the state of the art (would not be so unsatisfactorily small as possible in the case of TETRA) and would permit the use of modern mobile phone services by the BOS.
- XIV) The sentence and syllable understanding would be appreciably better because of the much better radio coverage.
- XV) The BOS would have finally and permanently caught up with the state of the art in digital radio.
- XVI) Mobile terminals would be less expensive because the mobile phone mass market permits huge production numbers: The BOS could dispense with special solutions wherever possible (e.g. for the paging service), make use of inexpensive products on the market and thus save a great deal of money.

Aachen, 24th February 2003

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