Analysis of radio transmission in Bavaria through DAB+ or LTE - comparing the costs of supply

broadcast or broadband ?

On the future of terrestrial radio supply

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Munich, March 2014

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Broadcast or Broadband? – on the future of terrestrial radio supply

Having just celebrated its 90th birthday, radio in Bavaria enjoys enormous popularity. With daily listening slightly up at 215 minutes, radio in 2014 firmly holds its ground against television and the internet competing for audiences. Even young people rate radio highly as a fast and reliable media which is available at any time and in any place.

Analogue transmission via FM, however, has become somewhat dated of late. As is the case for television, new offers and attractive programme-assisted services can only be realised in digital technology. Public-service broadcasting and commercial providers thus both face the challenge of mastering the impending media changeover.

Securing radio for the future therefore raises one fundamental question: Which digital technology can supply listeners everywhere in Bavaria with the greatest-possible range of radio programmes in the best way? For deciding this issue, it is necessary to assess future digital radio technologies with a view to their cost-efficiency, sustainability and feasibility in an international context and in a transparent and concrete fashion.

In November 2013, Swedish infrastructure provider Teracom presented a paper analysing the cost of terrestrial broadcasting transmission (DAB+) and terrestrial broadband (LTE); the paper was to provide information for the political consultation process. The analysis presented with this paper tries to provide answers to this economic and technical issue regarding future radio supply in Bavaria.

The analysis was commissioned jointly by the BLM and the BR from the Chair of Controlling at the TUM School of Management. Its findings provide valuable information answering the overriding issue of terrestrial radio supply via broadcast or broadband.

Munich, March 2014

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Commission for analysis

In December 2013, the Bayerische Landeszentrale für neue Medien (BLM) und the Bayerischer Rundfunk commissioned an analysis of the costs of terrestrial radio supply in Bavaria through the transmission standard DAB+ (digital audio broadcasting) compared to LTE (long term evolution). The analysis was prompted by a study presented in October 2013 by Swedish infrastructure provider Teracom and a-focus consultancy which looked at the suitability of the mobile internet as a substitute for the current terrestrial FM radio transmission in Sweden.[2]

The present analysis describes current radio consumption in Bavaria, compares the standards regarding their technical and regulatory suitability for radio supply and investigates their cost of transmission.

The frequency range applied for FM radio is limited to 87.5 MHz - 108 MHz, allowing only a very small number of programmes to be transmitted. Lower audio quality, the lack of transmission options for additional data[3] via FM and, above all, the limited number of programmes available, have convinced regulators, the state media authorities and radio providers of the need for a new infrastructure for terrestrial radio supply which offers a better performance. The available options which would allow for replacing the current FM broadcasting standard in an economically viable fashion are considered in the light of this scenario.

FM broadcasting can on principle be replaced by transmission via DAB+ or via LTE. The DAB standard was developed during the period 1987 – 2000 in the framework of the Eureka-147 project; in 2011, the DAB+ upgrade was released which allows for even more efficient encoding. In Bavaria, roll-out of the DAB/DAB+ infrastructure started as early as 1995. However, the digital standard initially met with little acceptance as very few programmes only migrated to the new standard. Purchase of new receivers for DAB+ radio also took up very slowly, and as a result, migrating to the new standard was not an option for most broadcasters. Although transmission costs for DAB+ are considerably lower than for FM, simulcast operation would be necessary initially until the majority of listeners has upgraded reception euqipment to DAB+ compatible sets. This would involve a considerable financial burden for the content providers. Due to the negative experiences gathered concerning the acceptance of DAB+ and the continually increasing web radio audience, radio transmission through the stationary and mobile internet is being increasingly propagated as an alternative to DAB+. The LTE standard in particular could provide the capacities required for mobile radio supply.

Transmission costs for radio programmes present a major factor in the decision as to which route of transmission to opt for. The following analysis therefore looks at the transmission costs for mobile radio consumption through DAB+ and through the mobile internet - both via the LTE unicast standard and via eMBMS (evolved Multimedia Broadcast Multicast Service).

[2] a-focus and Teracom (2013).
[3] RDS (Radio Data System) permits station names or traffic information to be transmitted.

Executive summary of the analysis

1. Radio broadcasting in Bavaria: the status quo

In Bavaria, users currently listen to approx. 795 billion minutes of radio per annum; consumption is almost exclusively via FM. For around 75 per cent of listening stationary equipment is used. While foregoing terrestrial broadcasting could therefore be compensated by resorting to indoor internet reception, mobile radio consumption which accounts for 25 per cent of total listening would have to be handled via a mobile infrastructure (LTE). Employing DAB+, however, all radio listening could be supplied via terrestrial broadcasting.

2. DAB+ and LTE and their suitability for future radio supply

In Section 2 of this analysis, DAB+ and LTE are analysed with a view to their suitability as regards radio transmission in Bavaria, looking both at the technological and the regulatory requirements concerning radio supply. The analysis finds that DAB+ as a standard is indispensable for radio transmission in the future. In particular, consumers do not face any costs for radio listening via DAB+. In addition, the DAB+ infrastructure can be embedded in a European-wide environment. Both of these aspects would point towards the continued expansion of the DAB+ infrastructure which has already started. Web radio will also gain in relevance, but it is unlikely to be able to replace DAB+ for the foreseeable future.

3. The costs of radio supply via the mobile internet (LTE or eMBMS) and DAB+ in comparison

If the further extension of the DAB+ infrastructure were discontinued, some 25 per cent of radio output would have to be handled through mobile radio for ensuring mobile reception. The annual data rate to be transmitted in Bavaria would be an enormous 133,231 TB. Radio supply via the mobile internet would therefore only be possible if the necessary infrastructure were heavily extended. Transmitting this amount of data, calculated at today's prices for mobile internet via LTE, would result in annual costs of EUR 616.7 million. Distributing 24 programmes via eMBMS would result in an annual expenditure of EUR 552.4 million. The cost of broadcasting 24 programmes through the DAB+ infrastructure would come to just EUR 15.5 million per annum following a major extension of the infrastructure. Transmitting 36 channels across all of Bavaria and 12 local programmes would bring expenses of around EUR 24.6 million per annum. These figures show that DAB+ offers a decided cost benefit. Transmission costs through LTE would exceed the cost of radio transmission via DAB+ by more than 40 times.

4. Conclusion

The analysis shows that the further extension of the DAB+ infrastructure is the appropriate way forward for ensuring future-proof radio supply. And even if the dominance of terrestrial broadcasting will decline as a result of the increased penetration of internet-enabled end devices and the connectibility of cars to the internet in the future, the extension of the DAB+ infrastructure is indispensable to ensure that the fundamental remit of broadcasting can continue to be met in a reliable and cost-effective way.

1. Radio in Bavaria: the status quo

In 2013, some 9.55 million people listened to radio in Bavaria every day. Radio thus has a daily reach of almost 88 per cent of the Bavarian population aged 10 years or older.[4] Every user on average listens to the radio 242 minutes per day during the week. Of these 242 minutes, 138 minutes are spent listening to the radio at home, 60 minutes are consumed at work, 36 minutes in the car and 8 minutes during other activities. This listening pattern would indicate that radio as a „passive" media in the car or at work is consumed as entertainment alongside the main activity.[5] The total annual volume of radio listening in Bavaria thus comes to around 800 billion minutes.

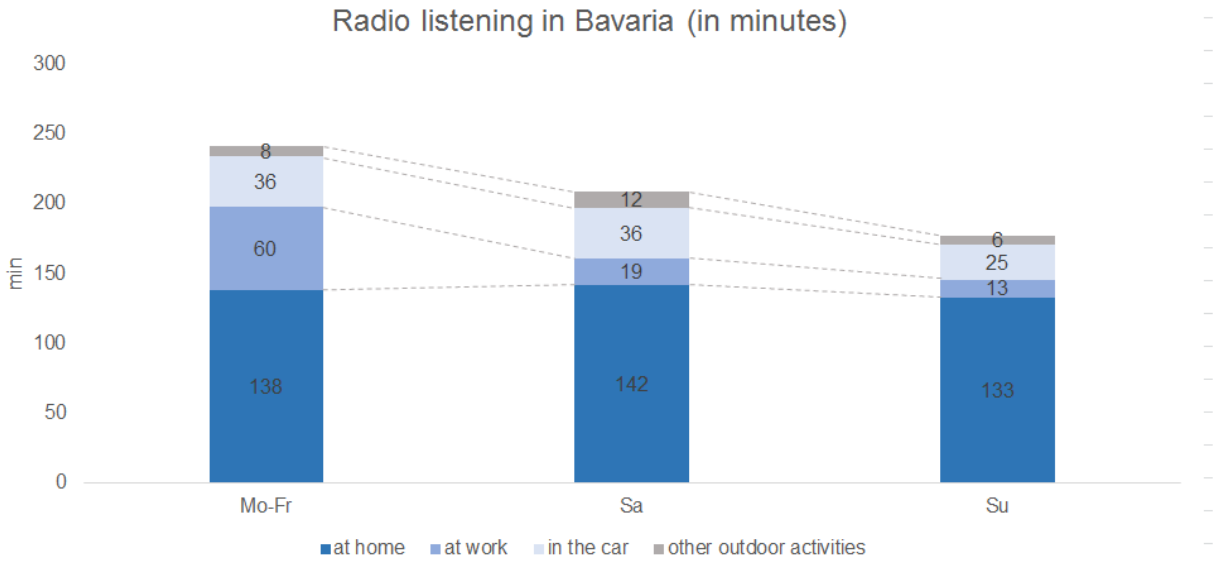

Figure 1: Average radio listening in Bavaria, in minutes by week days and activities[6]

Radio reception is strongly dominated by FM receivers. In Bavaria, there are some 25,844 million FM sets in the market while for listening to DAB+ radio, 827.000 devices are presently used. Of these sets, 278.000 are in-car receivers. Each household in Bavaria thus uses an average 4.4 FM radio sets.[7] 97.1 per cent of Bavarian households stated that they owned at least one FM receiver while only 7.5 per cent of homes own a DAB+ receiver. Radio reception on the computer is possible in 28.7 per cent of households, and 13.1 per cent of homes own a smartphone permitting radio reception.[8]

[4] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), p. 3.
[5] Was Radio besonders gut kann (2013), p. 11.
[6] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), pp. 16-17.
[7] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), p. 69
[8] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), p. 68.

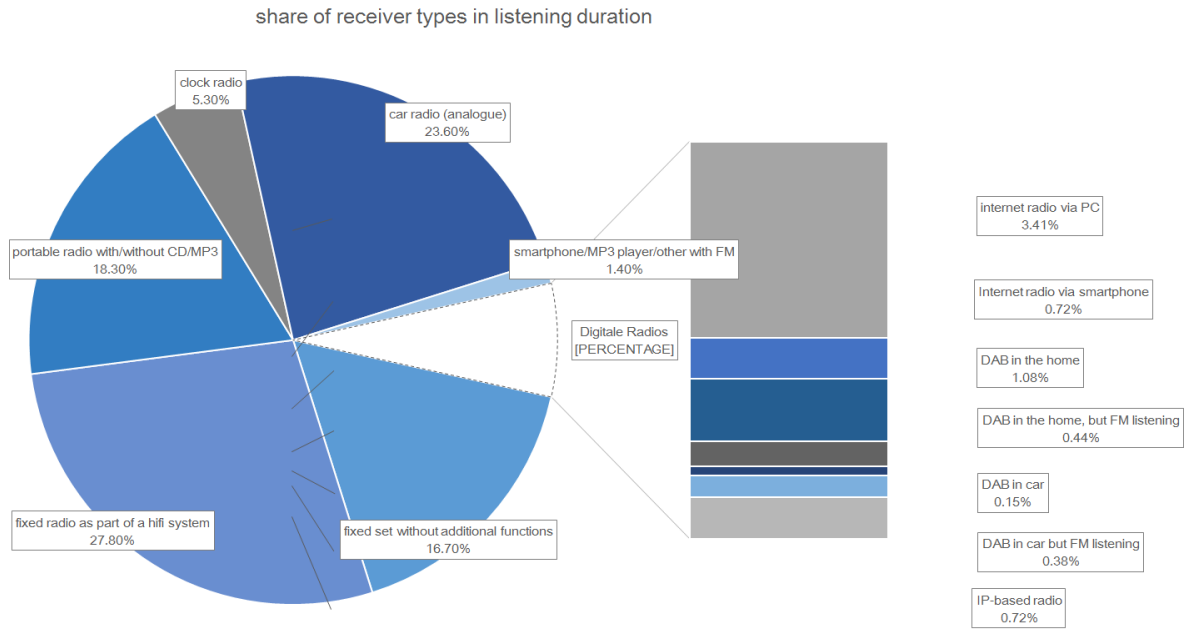

Figure 2: radio listening by type of radio receiver[9]

Total radio consumption in Bavaria is divided up into 80 per cent of sets in a household, and 20 per cent of sets outside of the home, e.g. at work or in the supermarket. Figure 2 outlines how radio is consumed in the household by type of receiver for the 80 per cent home consumption. The receiver base includes digital equipment such as computers, fixed sets which are part of a hi-fi system, fixed sets without additional functions, portable sets including CD/MP3 players, portable radio sets without additional functionalities, clock radios and other types of radio. Use of these receivers is mainly stationary (75 per cent). In the event of radio transmission through LTE[10] these sets could be supplied through the stationary internet via LAN/WiFi. The remaining 25 per cent would have to be supplied through the mobile internet; they include car radios, smartphones and MP3 players.[11] In the assessment of the LTE transmission costs, only the share of these sets is taken into account for overall listening. The analysis does not take into account sets at home or at work which could on principle be connected via LAN/WiFi but which are not connected to the internet due to lack of interest, individual circumstances or lacking availability of broadband. If they were taken into account, the radio share to be covered through LTE would grow further.

[9] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), pp. 77-78.
[10] LTE (Long Term Evolution) is a standard for wireless communication based on the GSM/EDGE and UMTS/HSPA network technologies permitting increased data transmission capacities and speeds.
[11] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), pp. 77-78.

2. DAB+ and LTE and their suitability for future terrestrial radio supply

Section 2 deals with the suitability of DAB+ and LTE for terrestrial radio supply in Bavaria, looking both at the technological and the regulatory framework for broadcasting.

2.1 DAB+ – the standard currently envisaged for future terrestrial radio transmission

2.1.1 DAB+ as a standard for radio transmission

The restrictions characterising FM, in particular limited transmission capacities and the constraints regarding the transmission of data services were already identified in the 1980s. The EU therefore initiated the Eureka 147 project which developed the DAB standard during the period 1987 - 2000; this was subsequently upgraded, resulting in the DAB+ standard in 2011.[12] Compared to FM, DAB+ allows for a more efficient use of frequencies, thus reducing the necessary transmission capacity.

DAB+ has already reached a significant penetration in Bavaria with 827.000 sets being available in Bavarian homes in 2013.[13] This corresponds to a penetration by population of around 7.5 per cent.[14] This is a significant increase compared to 2008 when only 109.000 sets were available in homes, corresponding to a penetration of around 1.1 per cent. Currently, the DAB+ infrastructure in Bavaria comprises two state-wide networks and four local networks. The state-wide network K 12D[15] uses 26 DAB+ transmitter stations currently offering mobile coverage of approx. 88 per cent of the Bavarian population.[16] Bayerischer Rundfunk plans to operate its digital network (K 11D[17]) using approx. 33 transmitter stations by the end of 2014. By 2017, the network is to be extended to 56 transmitters, allowing 97 – 99 per cent of the population to receive DAB+. Planning for the K 12D network comprises a maximum 42 transmitters for supply across Bavaria as a whole as the network is devised for the distribution of commercial programmes; this means that the intended coverage – unlike for public-service broadcasting – is to be established employing economic factors rather than the legal requirement to supply content for the entire population. Full coverage is therefore not required for the K 12D network. In addition, there are currently four local networks in operation in Bavaria, supplying the metropolitan areas of Munich (K 11C), Augsburg (K 9C), Ingolstadt (K 11A) and Nuremberg (K 10C).

Every network offers a transmission capacity[18] for 12 programmes at an audio quality bit rate of 96 kbit/s. Taking into account the state-wide networks, a total of 36 programmes of high audio quality can be transmitted in Munich and the other metropolitan regions.

2.1.2 The advantages of the DAB+ standard

DAB+ offers a number of advantages compared to radio transmission effected via mobile networks. The most important benefits include the infrastructure which is already in place, the possibility to receive radio without additional cost across European borders, minimum signal interference even at

[12] O'Neill, Brian (2009), pp. 261-278.
[13] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), p. 69.
[14] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), p. 68.
[15] Name of the transmitter network operated by Digitalradio Bayern GmbH. The network is devised for commercial content providers.
[16] http://www.bayerndigitalradio.de/digitalradio/verbreitung/. By comparison, current coverage is 54 per cent of homes.
[17] Name of the transmitter network operated by the public-service broadcaster, Bayerischer Rundfunk.
[18] Each network comprises a total capacity of 864 CU (capacity units). A data rate of 96 kbit/s and protection level 3 (PL) necessitate 72 CU; this allows a maximum 12 programmes to be transmitted in each DAB+ network.

high travel speeds, no costs incurred for listening to DAB+, and DAB+ meeting the regulatory requirements laid down for audio content.

As detailed in Section 2.1.1 both the K 12D network and the K 11D network in Bavaria will be extended from 2014 to 2017 to achieve an extensive coverage of the population. There are thus terrestrial DAB+ broadcasting capacities already in place and ready for use.

Figure 3 shows another relevant aspect advocating the further extension of the DAB+ infrastructure: According to developments in the neighbouring countries DAB+ appears to be established as a European standard. As most countries bordering Germany are also in the process of setting up DAB+ networks, a German or Bavarian strategy without DAB+ would result in reception equipment becoming unsuitable once a border is crossed. For many persons travelling between countries, internet radio does not present an option due to the high roaming costs incurred. Many listeners would not accept this disadvantage of pure web radio transmission.

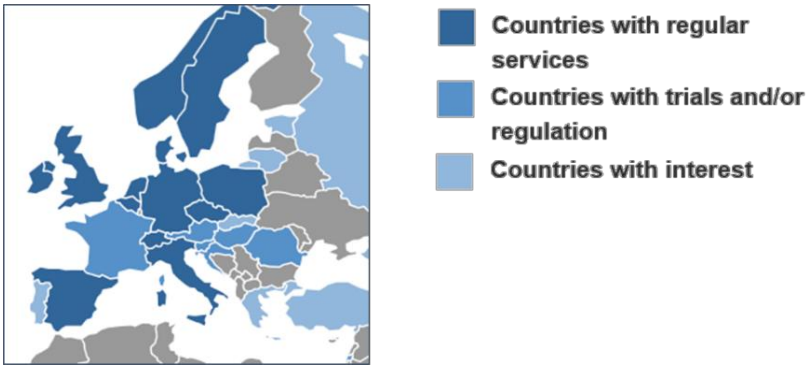

Figure 3: DAB+ map of Europe[19]

Transmitter networks for mobile telecommunications are built up considerably tighter than required for the DAB+ standard. In Bavaria, more than 11.000 mobile radio stations are currently in place; they are fitted with transmission systems in the order from one to more than six.[20] For the extension of the two state-wide networks K 11D and K 12D, a mere 112 transmitter stations are required. As the cell site network for mobile telephony is constructed much closer, a frequency change of transmitters would be required when listening to radio over the internet travelling at higher speeds, e.g. on a train or in the car. These changes can result in a noticeable deterioration of audio sound quality. Another problem of mobile radio consumption is the incomplete LTE network coverage. Moving into an area not covered by an LTE network, no radio reception in good quality would be possible any longer.

A further decisive advantage offered by DAB+ is the fact that – apart from the licence fee – reception using this technologies does not incur any additional costs for listeners in Germany or in another country. Once a receiver has been acquired, unrestricted consumption of radio is possible. For web radio, costs will always be incurred for data transmission, be it as a flat rate or a pay-per-unit model.

The regulatory provisions governing the provision of radio are laid down in the Interstate Broadcasting Treaty (RStV), the Telemedia Act (TMG) and the broadcasting legislation passed by the German states, e.g. the Bayerische Rundfunkgesetz (BayRG). The Broadcasting Treaty sets standard provisions for broadcasting which are enacted at state level. The RStV requires the public-service broadcasters to contribute to information, entertainment, and the formation of opinion of the population

[19] http://www.worldDAB+.org/country-information.
[20] http://emf3.bundesnetzagentur.de/statistik_standort.html and http://emf3.bundesnetzagentur.de/statistik_funk.html.

in their programmes.[21] As specified in Art. 2 of the Treaty, "broadcasting means a linear information and communication service; it means the provision and transmission of offers for the general public for simultaneous reception".[22] Bayerischer Rundfunk is required to ensure full coverage of Bavaria under the BayRG.[23] This regulatory requirement can be fulfilled employing DAB+ for radio supply.

2.1.3 Disadvantages of the DAB+ standard

Compared to LTE, low receiver penetration and the lack of interactivity for listeners present the main disadvantages of DAB+ when compared to LTE.

Currently, only 827.000 DAB+ sets are available in homes in Bavaria; in the last few years, however, a clear upwards trend is noticeable when considering that in 2008, a mere 109.000 DAB-compatible sets were owned. By comparison, there are currently more than 25 million FM devices in the market. The car industry could act as a major driver for DAB+ radio and its dissemination; this would, however, require a change of the current pricing policy under which a surcharge of EUR 200 – 300 is levied for the installation of a DAB+ receiver in a new car. DAB+ sets are not yet fitted as a standard in cars. Were listeners to experience the advantages DAB+ has to offer by comparison to FM reception while driving, they could well opt for DAB+ receivers at home, too. To date, no switch-off date has been set for FM transmission yet; there is thus no need for consumers to buy a new radio set, and content providers thus lack the incentives required to push the migration of content to DAB+.

As is the case for FM, DAB+ also does not offer a return channel. While it is possible to transmit additional data alongside the audio signal, listeners cannot personalise their radio consumption or retrieve additional information. This presents a major disadvantage of DAB+ radio transmission by comparison to web radio.

2.2 Web radio as a possible alternative to DAB+

2.2.1 LTE-based radio transmission

As an alternative to DAB+, radio could be transmitted via the stationary and the mobile internet. For mobile web radio which is of special significance for this analysis, two differing transmission technologies appear to be particularly suited. LTE as a standard for mobile telephony builds on the GSM/EDGE and UMTS/HSPA network technologies and allows for an increased rate of data transmission. LTE operates the „unicast“ principle under which an end device (e.g., smartphone) demands a specific content from a content delivery server which is then supplied. As a consequence, the number of end devices that can be supplied with content via a radio station is limited. By contrast, eMBMS builds on the LTE standard, but it is constructed like a broadcasting service. The standard can be used to transmit IP data from one radio station to several end devices. As regards this standard, the limitation set by the capacity of a transmitter station is not the number of receiving end devices, but the number of programmes transmitted. Assuming that the mobile phone operators are already pushing the capacity limits[24] of their networks, all transmitters destined for radio distribution would have to be upgraded. For near-full radio coverage, additional new locations for transmitters would be needed as the maximum radius of an eMBMS transmitter does not exceed 5 km.[25]

[21] RStV, §11.
[22] RStV, §2 I.
[23] BayRG, Art. 15 III Nr. 3.
[24] Otherwise, mobile telecommunications providers would not invest in their networks.
[25] Qualcomm (2012), p. 7.

Figure 4 outlines user behaviour, indicating that a growing percentage of the population is becoming aware of radio content offered via the internet. According to the BLM 2013 Webradio Monitor, 14 per cent of those questioned stated that they used web radio at least once a week. This corresponds to an increase of 250 per cent over 2004. The average duration of listening to online-only radio is 109 minutes; for FM / DAB radio simulcasts it is 88 minutes and for UKW / DAB sub brands it comes to 58 minutes.[26] Considering the average daily radio consumption of around 4 hours, web radio is currently of little significance yet.

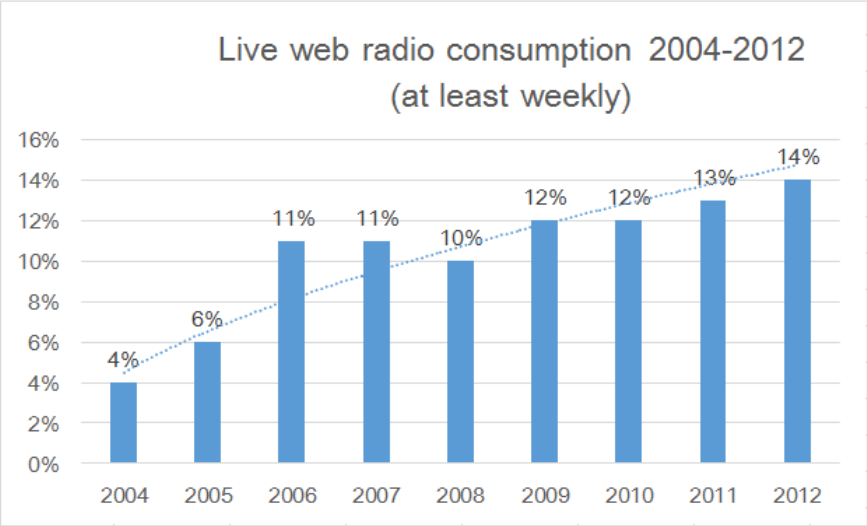

Figure 4: live web radio consumption in per cent, 2004 – 2012

2.2.2 The advantages of the LTE standard

LTE offers a large and varied programme range, interaction options for users, no local limitation of content provision and the automatic generation of the receiver base as advantages.

There is a wide range of radio services on offer via the internet. For Germany, the BLM Webradio Monitor identified 2.851 web radio channels. This figure is many times higher than the range of services offered via DAB+. The number of web channels is, however, going down slightly as it is difficult to make content pay in the internet.[27] Regarding their transmission infrastructures, 67 per cent of web radios are internet-only services while 13 per cent of the programmes offer FM/DAB+ simulcast; 20 per cent of channels simulcast their content via FM / DAB+ and use a specific brand for their internet radio.[28]

Alongside classic web radio content there are audio services allowing users to interact. It is, for instance, possible to create a play list in line with one's personal tastes, to directly purchase a song that has just be aired, or to check additional information on a performer. DAB+ cannot offer this return channel facility.

DAB+ is also characterised by content transmission being locally restricted. There are two nationwide DAB+ networks in Germany which are complemented by two networks covering all of Bavaria plus four local networks covering the major Bavarian metropolitan areas. Each broadcasting network, and consequently also each programme, is allocated to a dedicated broadcasting area. By contrast, radio

[26] Goldmedia GmbH Strategy Consulting / Bayerische Landeszentrale für neue Medien (BLM) (2013), p. 27.
[27] Goldmedia GmbH Strategy Consulting / Bayerische Landeszentrale für neue Medien (BLM) (2013), p. 12.
[28] Goldmedia GmbH Strategy Consulting / Bayerische Landeszentrale für neue Medien (BLM) (2013), p. 7.

distributed through the internet or mobile telecommunications networks does not have any limitations regarding coverage. As long as there is access to the internet, any radio content provided anywhere in the world can be consumed anywhere as long as it is not restricted by geo-blocking by the provider or by network interference (e.g., blocking).

As a further advantage of radio via LTE, the necessary receiver base generates itself automatically for users. With smartphones becoming ever more wide-spread among people, use of IP-based[29] radio is becoming possible more and more. In Germany, penetration of internet-enabled smartphones currently stands at 40 per cent and goes up by 17 per cent year on year.[30] Receiver coverage will thus still experience a marked increase, but full coverage will still take some years to be achieved. As regards DAB+ technology, users must acquire new end devices themselves to be able to listen to the radio via DAB+.

2.2.3 Disadvantages of the LTE standard

Comparing LTE and DAB+, the main disadvantage characterising LTE is the cost incurred for users for data transmission. Further disadvantages to be named are the necessary contract terms of the telecom provider, ncomplete LTE network coverage, lacking network neutrality and search neutrality, and potential roaming costs when using LTE abroad.

The greatest disadvantage concerning radio transmission via LTE is the cost listeners face. Data transmission in the mobile internet always causes expenditure, be it as a flat rate or as a pay-per-unit regime. The BMW Connected Drive System which offers a multimedia data flat rate for Germany and elsewhere is priced at EUR 390 in year one and at EUR 220 thereafter.[31] Radio listeners are not used to pay more than the licence fee for radio consumption; the additional costs described would therefore be hard to explain. Another factor is the contract which must be taken out with a telecommunications provider for listening to radio via LTE. There must be a SIM card in the end device and a contractual billing model has to be established for data rates transmitted and consumed. Listening to the radio anonymously is no longer possible. This fact also contradicts present listening habits and would require radio listeners to adjust their listening habits.

In the first quarter of 2013, LTE coverage in Germany was 45 per cent for Deutsche Telekom and 63 per cent for the Vodafone network respectively.[32] This means that major parts of the country are cut off from LTE technology. As Section 3 will show, investment for providing LTE coverage for the entire population would be considerable. It must therefore be assumed that LTE coverage will continue to remain patchy for the foreseeable future. As a consequence, LTE radio will be available in high quality only in some regions of Germany. Especially when travelling, the LTE technology as a standard is characterized by disadvantages compared to radio transmission via DAB+.

As regards regulation, transmission of public-service content exclusively via the internet would not be possible. The share of German households with access to the internet is currently stagnant at 76.5 per cent[33], with the rate in Bavaria just slightly higher at 77.1 per cent.[34] Near-complete coverage of the entire population is thus not given at this point. Another key argument weighing against public-service radio being transmitted exclusively via the internet is the aspect of net neutrality and the neutrality of

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[29] The Internet Protocol (IP) encodes data packets for transmission in the internet.
[30] http://www.bitkom.org/de/markt_statistik/64046_77178.aspx.
[31] http://www.pcwelt.de/ratgeber/BMW_macht_ConnectedDrive_guenstiger_und_umfangreicher-Texterkennung__Online_Entertainment__ConnectedDrive_Store-7942440.html.
[32] BNetzA (2013a), p. 46.
[33] Infratest T. N. S. (2013), p. 10.
[34] Infratest T. N. S. (2013), p. 20.

programme search.[35] In mobile telecommunications, specific data packages are granted preferential treatment. Capacities of transmitter stations are limited, and this could lead to a situation where it might not be able to handle the entire demand if a major event were transmitted. For warranting continuous radio reception, it would be necessary to exert preferential treatment for radio data streams which would constitute a breach of the principle of net neutrality. Treating different programmes on equal terms presents equal problems as they could be privileged in search engines and aggregators in such a way that this might impact the formation of public opinion.

As mentioned already in Section 2.1.2, roaming fees for listening to radio via the internet abroad could be considerable. This, too, is a central disadvantage of radio supply through mobile telecommunications networks as compared to transmission via DAB+

2.3 The suitability of DAB+ and LTE for terrestrial radio supply: conclusions

The suitability of DAB+ and LTE respectively for transmitting radio have been outlined in Sections 2.1 and 2.2 respectively; Table 1 summarizes the advantages and the disadvantages of the two technologies. It shows that the advantages of the DAB+ standard clearly outweigh those offered by LTE. Especially the cost aspect with DAB+ not causing any costs for listening, and the integration of the DAB+ infrastructure in a European-wide environment are arguments speaking for the continuation of the extension of the DAB+ network which is currently under way. Receiver penetration has also markedly picked up in the last years.

LTE does, however, offer some advantages over DAB+. The large range of programmes available via LTE, the option for listeners to interact and the automatic increase of the receiver base speak in favour of mobile web radio. The major disadvantages presented by radio transmission via LTE, especially the costs incurred for users during data transmission, the necessary contractual terms with the respective telecommunications provider, the lack of net neutrality and ensuing roaming fees abroad are factors due to which LTE can function as a complementary infrastructure alongside DAB+ but cannot replace it. In addition, public-service broadcasters are bound by legislation to provide content for the greatest part of the population; this remit can be fulfilled only using terrestrial broadcasting for some time to come.

Lastly, both DAB+ and internet radio are characterized by a latency factor of several seconds compared to FM radio. This delay is owed to avoiding signal interference for both technologies, and could be irritating when listening to the transmission of a sport event or similar. The latency thus presents a disadvantage of both technologies compared to FM radio.

[35] die medienanstalten – ALM GbR (2013), pp.14-17.

	DAB+	*LTE*
Advantages	▪ use of existing transmission infrastructure ▪ corresponds to radio in neighbouring countries in Europe ▪ minimum signal interference, even at high speeds ▪ no cost incurred for listening ▪ DAB+ meets regulatory requirements ▪ Full coverage of area and publication foreseeable	▪ very high range of programmes ▪ offers interactivity options to listeners ▪ no local restrictions for programmes ▪ automatic generation of receiver base
Disadvantages	▪ low receiver base ▪ no interactivity option for listeners	▪ Costs of radio consumption for listeners ▪ Contractual link to network provider required ▪ Incomplete coverage of network ▪ breach of net neutrality and search neutrality ▪ possibly roaming fees abroad

Table 1: The advantages and disadvantages of DAB+ and LTE at a glance

3. The costs of radio supply via the mobile internet (LTE or eMBMS) and DAB+ in comparison

The costs incurred for the transmission of radio content present a decisive factor regarding the decision on the transmission infrastructure. Below, the transmission costs for mobile radio listening via the mobile internet – both for the LTE unicast mode and the eMBMS multicast mode – and for DAB+ are analysed. Section 3.1 outlines the key cost factors of the different distribution infrastructures while Section 3.2 offers a comparison of the transmission costs of the different systems in relation to current radio consumption. Future radio consumption, user behaviour and the future cost of transmitting a data unit are difficult to assess; Section 3.3 therefore looks at different scenarios.

3.1 The cost drivers of the different transmission infrastructures for mobile radio

3.1.1 Cost drivers in transmitting radio in LTE networks

When radio is supplied through LTE, transmission is effected principally in the unicast mode, i.e. the information is transmitted individually to the end device of each listener. The data rate transmitted and the cost of transmission thus depend significantly on overall mobile radio consumption. The overall data rate for distribution also depends on the data rate required for the transmission of the radio signals. Typical data rates for radio transmission vary from 48 kbit/s to 127 kbit/s, depending on audio quality. Audio on demand services typically start at data rates of 96 kbit/s.[36]

Transmission costs in the LTE network overall thus result from the data rate to be transmitted and the price per data unit charged by the telecommunications providers.

In 2013, radio listening in Bavaria totalled approx. 795 billion minutes.[37] As outlined in Section 1, a large part of this consumption can be assumed to be met via the stationary internet. Coverage of a mere 25 per cent via mobile radio, as outlined in Section 1, would result in a data volume totalling approx. 133,231 TV per annum[38] for mobile radio in Bavaria applying a data rate of 96 kbit/s. At present, the entire data rate transmitted via the mobile internet in Germany overall totals approx. 140,000 TB.[39] Mobile radio transmission would thus basically double this data volume. As existing capacities could not handle this additional data rate, capacities would have to be massively expanded. In the LTE networks alone, 41 malfunctions impacting data transmission were reported during the period 9 February 2013 – 9 February 2014 across Germany.[40]

3.1.2 Cost drivers in transmitting radio in the eMBMS mode

Comparing the data volume required for the mobile internet which would result from giving up transmission in the broadcast mode and the data volume transmitted in the mobile internet overall, unicast transmission would appear to be a loss-maker. Transmitting identical data individually to a large number of users simultaneously would strain the limited capacities and cause considerable expenditure. As outlined in Section 2, the eMBMS standard offers an option even for LTE networks for multicast data transmission; the bandwidth required does not depend on the number of users accessing the data. This would, however, require all LTE base stations in Bavaria transmitting all available programmes at the same time.

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[36] http://www.audio.de/vergleichstest/6-musik-streamingdienste-im-test-1308466.html.
[37] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), p.2, p.16.
[38] The calculations of this analysis are based on leap years of 365.25 days per annum.
[39] BNetzA (2013), p. 79.
[40] Analysis based on network interferences as reported by heise online (http://www.heise.de/netze/netzwerk-tools/imonitor-internet-stoerungen/stoerungsmeldungen-suchen/).

The overall data rate incurred in the transmission via eMBMS thus results from the number of base stations in the LTE networks and the number of programmes to be transmitted through the base stations. Here, too, transmission costs overall depend on the cost incurred for distributing the data volumes.

3.1.3 Cost drivers in transmitting radio via DAB+ networks

To enable full coverage via LTE transmission, the LTE networks would have to be extended further. From the cost angle, the question arises whether it would be advisable to further extend the DAB+ network. Employing the DAB+ technology, data are transmitted in so-called *ensembles*. Setting up an ensemble allows a total of 864 capacity units (CU) to be transmitted. A *protection level* offers the redundancy of the data transmitted for failure correction. A medium *protection level* requires 72 CU for transmitting a programme at 96 kbit/s quality. An ensemble thus allows for up to 12 programmes to be transmitted. The only factor exerting an influence on transmission costs for DAB+ is the number of ensembles. Overall annual transmission costs do not change for up to 12 programmes per ensemble.

3.2 Annual transmission costs based on current consumption in comparison

3.2.1 Annual costs for transmitting radio via the mobile internet, unicast (LTE)

As detailed above, radio consumption in Bavaria is an annual 795 billion minutes. Based on the listening duration by receiver type (see Section 1) it is assumed that 25 per cent of the sum total cannot be covered via the stationary internet; this means that approx. 199 billion minutes of radio consumption would have to be supplied via LTE. This corresponds to a total 133,231 TB for a transmission rate of 96 kbit/s. At present, the transmission rate for one GB is EUR 4.52[41]. The annual transmission costs would thus be approx. EUR 617 million for transmitting current mobile radio consumption via LTE.

It has to be taken into account that the costs calculated for LTE distribution relate to the transmission of mobile radio only, i.e. to 25 per cent of radio consumption overall, while DAB+ could supply the entire audience at the cost calculated. Were DAB+ transmission given up, additional costs would result for radio reception over the stationary internet.

[41] EUR 4.50 Euro is the price per GB payable by the end consumer. Feeding into the content delivery network adds EUR 0.02. The prices were derived from the offers of Telefónica Germany GmbH & Co. OHG (http://www.o2online.de/tarife/datentarife/) and of Amazon Web Services, Inc.(http://aws.amazon.com/de/cloudfront/pricing/).

average number of radio listeners in Bavaria per day	9.55	million
average daily listening duration	228	minutes / day
total annual radio consumption across Bavaria overall	795	billion minutes / year
share of mobile radio in radio consumption overall	25	Per cent
annual mobile radio consumption across Bavaria overall	199	billion minutes
data rate	96	kbit/s
total annual data rate transmitted for mobile radio across Bavaria overall	133,231	TB
cost per GB, feed	0.02	EUR / GB
annual transmission costs	**2.7**	**million EUR**
cost per GB, reception	4.5	EUR / GB
annual costs of reception	**613.9**	**million EUR**
total annual costs across Bavaria overall	**616.7**	million EUR

Table 2: annual costs of radio transmission via the mobile internet, unicast (LTE)

3.2.2 Annual costs for transmitting radio via the mobile internet, multicast (eMBMS)

For the calculation of the cost of eMBMS transmission the number of transmitter stations required and programmes offered must be assumed. According to Qualcomm (2012), an eMBMS transmitter station in an urban area has a range of 288 m; for densely populated regions the range is assumed to be 1 km, in rural areas it is given as 5 km.[42] The Bavarian Statistical Office classifies 0.7 per cent of Bavaria as urban areas, 5.1 per cent as densely populated, and 89.2 per cent as rural[43]. Covering these areas with "alveolar" radio cells requires approx. 4,700 base stations per network; for three telecommunications providers, a total 14,100 base stations are needed.[44] This is about half of the mobile radio stations currently installed in Bavaria.[45] The stations handle all existing types of network (GSM/EDGE, UMTS/HSPA and LTE) which cannot at present offer full coverage. Concerning the content offered it is estimated that the overall share of current radio consumption could be met offering 24 programmes. The data rate of 96 kbit/s would thus result in a data volume for transmission totalling 119,348 TB per annum which is only slightly less than the volume calculated for unicast transmission. To date, little experience has been gathered regarding the use of eMBMS. There is no information concerning the billing of listeners or content providers for distributing radio content via eMBMS. As laid out above, further costs would ensue from the set-up of eMBMS facilities. For the benefit of eMBMS, however, it is assumed in the analysis that the transmission of 1 GB through the eMBMS multicast mode per programme would result in the same costs in the long term as for the transmission

[42] Qualcomm (2012), p.7.
[43] Urban areas are defined as areas with a population in excess of 2.500 inhabitants / km^2, densely populated areas areas defined as ≤2.500 and >450 inhabitants per km2, rural is defined as an area with less than 450 inhabitants per km^2.
[44] It is assumed that 5 per cent of the area of Bavaria do not require any supply due to lacking development. For developing the remaining area, development in hexagonal alveolar forms is assumed. For each network, approx. 2,357 transmitters are needed in urban areas, 1,384 transmitters are required in densely populated areas and 969 transmitters are needed in rural areas.
[45] http://emf3.bundesnetzagentur.de/statistik_standort.html and http://emf3.bundesnetzagentur.de/statistik_funk.html.

of 1 GB through the LTE unicast mode to a listener. This would result in annual transmission costs of the eMBMS mode of approx. EUR 552 million.

base stations for LTE transmission needed in Bavaria (for all telecommunications providers)	14.100	
Radio programmes	24	
Data rate	96	kbit/s
total annual data rate transmitted for feeding mobile radio across Bavaria overall	119,348	TB
cost per GB, feed	0.02	EUR
annual transmission costs across Bavaria overall	**2.4**	**million EUR**
cost per GB, reception	4.5	EUR / GB
annual reception costs	**550.0**	**million EUR**
total annual costs across Bavaria overall	**552.4**	million EUR

Table 3: annual costs of radio transmission through the mobile internet, multicast (eMBMS)

3.2.3 Annual costs for transmitting radio via DAB+

The annual cost for 60 CU transmission capacity in the Bavarian-wide channel is currently EUR 250.000 and allows for the transmission through 26 transmitters across all of Bavaria.[46] These 26 transmitters reach only 56 per cent of the population and cover around 88 per cent of the area of Bavaria.[47] A network covering 97 – 99 per cent of the area would require an extension to around 56 transmitters. At constant costs for 1 CU per transmitter, the price forecast per CU at a corresponding coverage would be approx. EUR 8,974 across Bavaria overall. Annual transmission costs for one ensemble consisting of up to 12 programmes with 72 CU each would thus be approx. EUR 7.8 million.

The DAB+ network in Bavaria currently offers three to four ensembles, depending on the regions. The two Bavarian-wide ensembles are complemented by a nationwide ensemble and local ensembles in the areas of Augsburg, Ingolstadt, Nuremberg and Munich, adding some ten transmitters for these ensembles. Were the programmes offered in these ensembles to cover the entire current radio consumption, costs of approx. EUR 24.6 million would ensue. Calculating the costs for 24 programmes, i.e. two ensembles, as in the calculation for eMBMS transmission detailed above, annual expenditure would come to approx. EUR 15.5 million.

[46] Bayern Digital Radio GmbH (2014), p.1.
[47] http://www.bayerndigitalradio.de/digitalradio/verbreitung/.

current costs for 60 CU across Bavaria overall	250.000	EUR
current cost for 1 CU across Bavaria overall	4,166.67	EUR
current number of transmitters in the CAB+ network across Bavaria overall	26	
transmitters required in the DAB+ network at full network extension across Bavaria overall	56	
forecast cost of 1 CU across Bavaria overall at full network extension	8,974	EUR
forecast cost for 1 ensemble (864 CU) across Bavaria overall at full network extension	7.8	million EUR
annual transmission costs across Bavaria overall, 24 programmes transmitted with 72 CU each	**15.5**	**million EUR**
annual costs of reception	**0**	**million EUR**
total annual costs across Bavaria overall, 24 programmes	**15.5**	**million EUR**
total annual costs across Bavaria overall, 36 programmes + 10 programmes in regional ensembles	**24,6**	**million EUR**

Table 2: annual costs of radio transmission through DAB+

3.3 The key factors impacting annual transmission costs

As illustrated in Section 3.2, DAB+ at EUR 24.6 million or EUR 15.5 million per annum offers clear cost advantages over radio transmission via eMBMS (EUR 552.4 million) or via LTE (EUR 616.7 million). Consumer behaviour, but also the cost incurred for the mobile internet considerably impact these results: Whereas the costs for eMBMS depend only on the number of programmes, the costs for LTE depend on radio consumption overall. As regards DAB+, the cost for 12 programmes remain constant, independently of the number of listeners.

3.3.1 Transmission costs per listener and programme by transmission infrastructure

Costs for the transmission in the LTE unicast mode go down per programme when the number of listeners goes down; for transmission via DAB+ or the eMBMS multicast mode, the transmission costs remain unchanged. Whether an additional transmission via DAB+ is worthwhile will therefore depend considerably on the number of listeners wishing to simultaneously consume the same programme. At the assumptions detailed above, the price per minute of listening will be EUR 0.31 in the LTE transmission mode. A Bavarian-wide ensemble transmitted in the DAB+ mode generates annual costs of approx. EUR 7.8 million. At full load with 12 programmes, the annual costs per programme are approx. EUR 646.000. By comparison, however, the costs for transmitting just one programme in the eMBMS is approx. EUR 23 million per annum. Transmission in the eMBMS mode will therefore pay only if the cost per GB transmitted goes down to a fraction of the present price. Section 3.3.3 takes a closer look at the influence of costs per transmitted data volume in the mobile internet.

LTE with eMBMS	DAB+
cost of one programme transmitted via eMBMS across Bavaria overall	cost of one programme transmitted via DAB+ at full ensemble use across Bavaria overall
23.02 million EUR / year	**0.65 million EUR / year**

Table 3: Costs for the transmission of one programme in the eMBMS and the DAB+ mode respectively

In this context, it should not be ignored that transmission via LTE as described above would cover only 25 per cent of radio reception which is currently effected largely in terrestrial mode. The remaining 75 per cent will also have to be transmitted by the content provider and consumed on-demand by the user; this again results in costs.

3.3.2 Development of radio consumption

When assessing the future development of radio consumption, several effects must be taken into account which are in part opposing each other: the further development of audio content provided for on-demand consumption might tend to result in demand for radio going down. It is hard to assess how strong this effect might be. It can be expected that a wider choice of programme offers will increase radio consumption overall. The DAB+ standard allows for the transmission of a considerably higher number of programmes than is possible via FM at present; this could again lead to more radio being consumed. In addition, mobile radio consumption in particular is more difficult to substitute. It can be assumed that substitution will be lower for in-car consumption and radio listening at work due to handling issues and the wish for up-to-date information. A possible trend could be stronger segmentation, i.e. audiences being distributed across more programmes, resulting in lower listener figures per programme. The following analysis looks at the question when (i.e. as of how many hours of listening per annum) radio supply through DAB+ becomes more cost-effective than through LTE unicast.

If an ensemble is operated at the full capacity of 12 programmes, transmission via DAB+ pays from a rate of 3.47 million mobile listeners per hour per annum; this would correspond to 9,500 daily listening hours or a market share of approx. 0.1 per cent in current mobile radio consumption overall.

Annual number of listening hours as of which transmission via DAB+ pays for a Bavarian-wide programme (at full-capacity operation of an ensemble (million hours)	3.5
This corresponds to a market share of current mobile radio consumption of...	0.10%

Table 4: annual listening hour, from which DAB+ transmission pays

3.3.3 Development of transmission costs for the mobile internet

A key factor impacting the transmission costs of LTE and eMBMS overall is the cost incurred for mobile internet. Assuming that the complete current radio consumption can be transmitted using two DAB+ Bavarian-wide ensembles, one nationwide ensemble and four local ensembles, the price for mobile internet would have to drop to approx. EUR 0.18 per GB for transmission through LTE to be a worthwhile financial option.

In this regard, note must be taken that some of the programmes could be transmitted via eMBMS in the multicast mode, and programmes attracting fewer listeners might be distributed across the LTE unicast mode. This option would result in the following scenario:

annual number of listening hours per programme from which transmission via eMBMS is cheaper than via LTE	123.6	million hours
market share from which transmission via eMBMS pays in comparison to transmission via LTE in the unicast mode	3.7	Per cent
number of programmes with a higher market share for which transmission via eMBMS would pay	3	
total market share of the remaining programmes	33.3	Per cent
annual data volume transmitted for three programmes distributed via eMBMS	14,919	TB / year
remaining data volume for LTE transmission	44,366	TB
total data volume to be transmitted in a combination of eMBMS and LTE in the unicast mode	59,284	TB
total annual cost across Bavaria overall for transmission via DAB+	24.6	million EUR / year
Maximum transmission costs for 1 GB in the LTE network for achieving cheaper transmission via the LTE network than via DAB+	**0.42**	**EUR**

Table 5: calculation of maximum data transmission costs for making data transmissions via LTE cheaper than via DAB+

Transmission in the eMBMS multicast mode starts to pay from approx. 124 million listening hours for one programme when compared to the transmission in the LTE unicast mode. This is equivalent to a market share of 3.7 per cent: Antenne Bayern, Bayern 1 and Bayern 3. These three programmes have a combined market share of 66.7 per cent.[48] Transmission of three programmes via eMBMS and another 33.3 per cent of current mobile radio consumption via LTE in the unicast mode would result in the data volume for transmission totalling approx. 59,284 TB. The forecast of annual cost of EUR 24.6 million incurred for the transmission via DAB+ thus means that the price per GB would have to go down to a maximum EUR 0,42 to make transmission via LTE worthwhile in the scenario outlined above.

The high fixed cost of investment and the pressure on prices which is already considerable due to the extremely competitive mobile market make it unlikely that a reduction of cost from currently EUR 4.52 to EUR 0.42 would occur.

[48] TNS Infratest / Bayerische Landeszentrale für neue Medien (BLM) (2013), p.4.

4. Conclusion

DAB+ and LTE present two technical options for terrestrial radio transmission. Some sections of the population are already able to use both alternatives. However, neither DAB+ nor mobile internet currently offer full coverage.

In conclusion of this analysis, the further extension of DAB+ for providing full coverage presents the economically sensible and only realistic option available to allow for near-full coverage of digital radio in Bavaria in the foreseeable future. Radio reception via LTE while gaining in significance still cannot offer a sufficient contribution to the full coverage of Bavaria for the foreseeable future due to the high cost incurred for network extension and transmission.

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Conclusions for the further development of commercial radio in Bavaria

The present analysis contains a purely economic analysis and assessment of DAB+ and LTE for the theoretical replacement of FM for providing terrestrial radio in Bavaria. The analysis finds that from an economic point of view for ensuring a future-proof terrestrial radio supply in Bavaria in the years to come, the further extension of the DAB infrastructure presents the correct way forward. This conclusion holds good at least for the next 10 – 15 years. Providing terrestrial radio exclusively via LTE would be around 40 times more costly than transmission via DAB+; it would present a massive risk for the economic viability of commercial radio in a large state such as Bavaria, and would also make it impossible for the BLM to fulfil its legal remit in a responsible fashion. Furthermore, consumers would face noticeable costs for listening to radio. These aspects therefore raise principal doubts whether using such an infrastructure would be socially acceptable. In addition, radio transmission via LTE could not offer non-discriminatory access to all walks of society in the way in which it is the case today and would therefore be hard to explain from a political point of view. And the financial means of the BLM and their foreseeable development would not allow for promoting an exclusive LTE radio infrastructure from today's viewpoint.

In the view of the BLM, the set-up and further extension of the DAB infrastructure as an option offers greater sustainability. In the interest of the responsible development of radio in Bavaria, the BLM together with public-service broadcasting banks on an accelerated migration from FM to DAB+ in the coming years without excluding the additional provision of terrestrial radio via LTE. The focus is therefore increasingly set on hybrid reception options. The BLM considers the use of hybrid receivers, for instance integrating the multi-standard Eurochip or the combination of broadcast signals and internet content with the aid of RadioDNS presenting good opportunities for providers and consumers of commercial radio to effect a smooth changeover from analogue to digital terrestrial radio.

The preferred utilisation of DAB+ allows commercial broadcasting in Bavaria to participate in the digital development of radio – both in Germany and elsewhere in Europe – and to keep its competitiveness both vis-à-vis public-service broadcasting and vis-à-vis internet-based audio services.

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Conclusions for public-service broadcasting in Bavaria

The present analysis which compares the costs of radio transmission via LTE mobile radio networks and DAB+ networks allows for clear conclusions concerning the economics of terrestrial radio supply. For public-service broadcasting in particular, easy, non-discriminatory and universally available access to its contents is of key importance. This requires low-cost transmission networks offering full coverage. The decision concerning the future-proof and sustainable provision of broadcasting over the coming 10 – 15 years is therefore of major significance.

According to the analysis, the route to follow is the further extension of the DAB infrastructure. Not only would transmission via LTE cause approx. 40 times the cost, but fulfilling the objective of supplying public-service broadcasting via LTE would be more than doubtful employing LTE as the target of extending a commercially operated mobile telecommunications networks by nature does not match the objectives and remit of public-service broadcasting as regards content provision. Furthermore, consumers would have to pay clearly more for listening to radio via LTE. The legal remit of the BR which has to supply all parts of the population with its contents in a low-cost and non-discriminatory fashion could not be realised by transmitting its radio programmes via LTE.

The Bayerische Rundfunk therefore jointly with the BLM rates the further extension of digital radio supply via DAB+ the right option which also presents the best solution regarding the foreseeable medium-term to long-term possibility of migrating radio transmission from analogue to digital radio. As a complement to linear terrestrial supply at home, WiFi already presents a useful option for hybrid receivers while for the consumption of non-linear content, the combination of "WiFi at home" and "LTE on the road" is a choice offering a future.

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