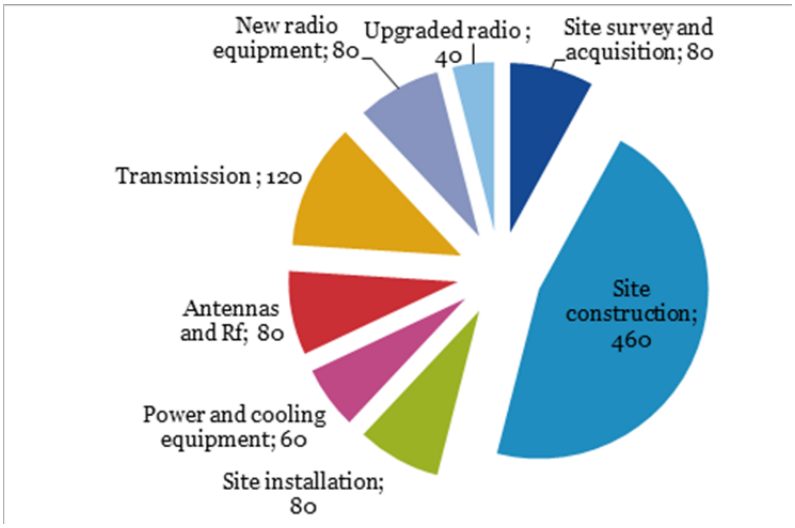
EXAM IK2514 January 14, 2014, 14.00-18:00

The exam consist of 5 problems, Appendix A and B with text to analyze for problem 4.

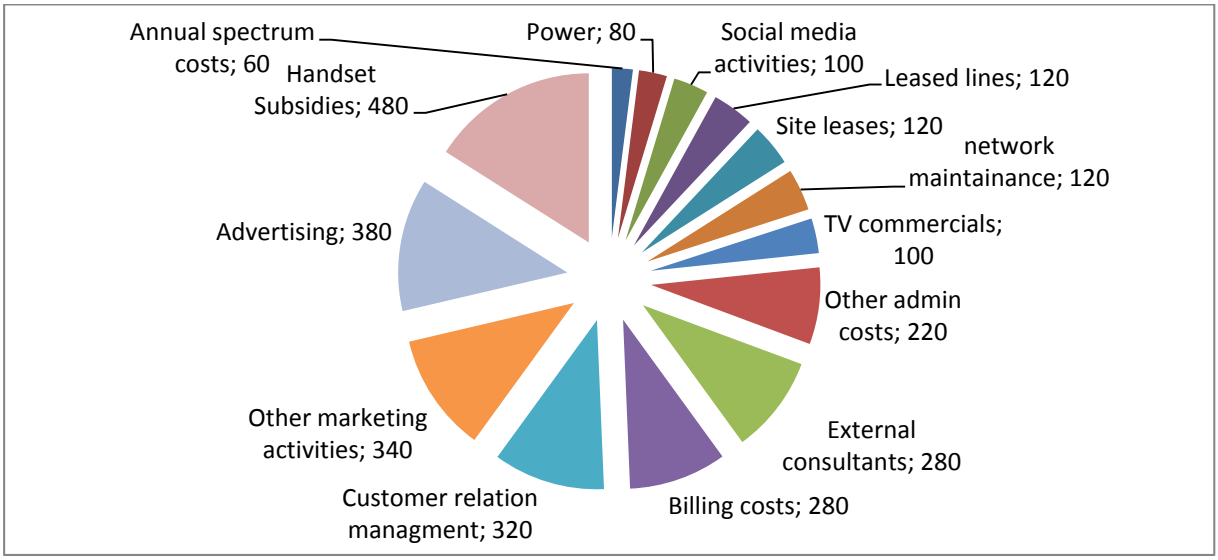
Problem 1: Network sharing (2p)
Network sharing is used by mobile operators usually in order to reduce network costs.

Question a)
Mention (and motivate) two other reasons besides cost reduction that may motivate a mobile operator to share network with a competitor? (1p)

Question b)
Consider two operators with equal costs and cost structure for a number of years.
What can be shared and how much can each of the operators save by network sharing? (1p)
See cost structure below, assume that all types of network related costs are reduced by 1/3 (33,3%)



Investments for one operator during the period



Running costs for one operator during the period

Solutions problem 1:

Question a)
All relevant and well-motivated reasons will be considered, examples are:

- To get access to spectrum license, e.g. Telia that did not get any 3G licence
- For a market entrant or small operator to get access to existing network (sites)
- For minor operators to be able to compete (e.g. on coverage) with the market leader

Other aspects that are important (but probably not key drivers) are:

- For a new actor: To get access to competence
- To combine spectrum (higher bandwidth), spectrum aggregation provides a possibility to offer higher data rates, i.e. a better offer

Question b)
What can be shared and how much can each of the operators save by network sharing?

Operators share all network related types of resources like sites, radio, equipment
but they do not share anything that is related to marketing, customers, billing etc

All investments are network related, in total 1000 (M€).

For running costs identify what is network related and not, see table below
Network part is 500 M€ (out of a total of 3000)

Network related costs in total: 1000 + 500 = 1500;
33% reduction means savings of 500 (M€)

Type	OPEX	M€
networks	Site leases	120
networks	Power	80
networks	Leased lines	120
networks	Annual spectrum license cost	60
networks	Network maintainance	120
Marketing	TV commercials	100
Marketing	Advertising	380
Marketing	Handset Subsidies	480
Marketing	Other marketing activities	340
Marketing	Social media activities	100
Customers	Billing and platform costs	280
Customers	Customer relation management	320
Customers	External consultants	280
Customers	Other admin costs	220

Problem 2: Questions related to the financial toolbox (4p)

I. Concepts (1 p)

a) Please define and explain what the following concepts stand for (0.5 p)

EBITDA – It is an acronym for earnings before interest, taxes, depreciation and amortization. The EBITDA of a company gives an indication of the current operational profitability of the business i.e., how much profit does it make with its present assets and its operations on the products it produces and sells.

Opex - An operating expense, operating expenditure, operational expense, operational expenditure or OPEX is an ongoing cost for running a product, business or system, like a network operation.

Capex - Capex (or Capital Expenditure) is a business expense incurred to create future benefit i.e. acquisition of assets that will have a useful life beyond the tax year. e.g. expenditure on assets like network, building, machinery, equipment or upgrading existing facilities so their value as an asset increases.

b) What is gearing? And what does the relation between net debt and EBITDA, respectively net debt to Enterprise value say? (0.5 p)

Gearing is the level of a company's debt related to its equity capital, usually expressed in percentage form. Gearing is a measure of a company's financial leverage and shows the extent to which its operations are funded by lenders versus shareholders.

Net debt to EBITDA is a measurement of leverage, calculated as a company's interest-bearing liabilities minus cash or cash equivalents, divided by its EBITDA. The net debt to EBITDA ratio is a debt ratio that shows how many years it would take for a company to pay back its debt if net debt and EBITDA are held constant. If a company has more cash than debt, the ratio can be negative.

Enterprise value is a measure of a company's value. Enterprise value is calculated as market cap plus debt, minority interest and preferred shares, minus total cash and cash equivalents.

Net debt to Enterprise value is a measure of the level of debt in relation to the total value of a company. It shows how large debt a company has, and how it is financed.

II. Analysis of Case (3 p)

Operator Edge is an operator in a competitive market with four operators. Management is discussing how the business should develop up until 2020. One of the managers has provided a business plan in excel to you (see below for the numbers) and it needs to be complemented with some numbers. When the CEO (chief executive officer) is going through the numbers he is concerned over a couple of issues and you are asked to clarify and assist.

a) The market share is estimated to remain at 16.5% which the CEO regards as way too conservative. The CEO wants to see growth and the market share to increase to 25% by 2020. If operator Edge would gradually increase its market share and reach 24.9% by 2020 (increase with 120 basis points per year, from 16.5% in 2013 to 17.7% in 2014 and so on) would it have sufficient capacity with the current investment plan? The network has 2000 sites by 2013 and the plan is to increase the number of sites with 50 per year while the amount of spectrum 40 MHz is unchanged. (1 p)

	2011	2012	2013	2014e	2015e	2016e	2017e	2018e	2019e	2020e
Country data										
population million	10	10	10,1	10,2	10,3	10,4	10,5	10,6	10,7	10,8
Mobile penetration	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Mobile subscribers	9,50	9,50	9,60	9,69	9,79	9,89	9,98	10,08	10,19	10,29
Operator Edge										
Market share	15,0%	15,5%	16,5%	16,5%	16,5%	16,5%	16,5%	16,5%	16,5%	16,5%
Subscribers million	1,43	1,47	1,58	1,60	1,61	1,63	1,65	1,66	1,68	1,70
Revenues MEUR		20,62	22,16	22,39	22,61	22,84	23,06	23,30	23,53	23,76
Sites	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Additional sites				50	50	50	50	50	50	50
Total number of sites	2 000	2 000	2 000	2 050	2 100	2 150	2 200	2 250	2 300	2 350
Sectors per site	3	3	3	3	3	3	3	3	3	3
Spectrum MHz	40	40	40	40	40	40	40	40	40	40
Throughput bit/Hz	2	2	2	2	2	2	2	2	2	2
Capacity per site Mbit/s	240	240	240	240	240	240	240	240	240	240
Demand per user Mbps	0,09	0,09	0,10	0,11	0,12	0,13	0,14	0,16	0,17	0,19

Answer a)

The capacity is sufficient to support the growth plan and go for 25% market share by 2020

b) One way to reach the market share target of 25% by 2020 would be to offer lower prices which leads to that average revenue per user (ARPU) drops by EUR 0.5 per user and month, and offer more generous data packages. How would that impact total annual revenues for the period 2014-2020, and assuming that the market share goes up to 24.9% by 2020? (1 p)

Answer b)

See table below . Based on an ARPU of EUR 14 in 2013, and with a drop of EUR 0.50 per year up until 2020 it will reach EUR 10.5 by 2020. The impact on total revenues (compared to the base case in the first table) will be that it will increase with EUR 0.77 m 2014 up to EUR 3.13m 2020, according to the table below.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country data										
population million	10	10	10,1	10,2	10,3	10,4	10,5	10,6	10,7	10,8
Mobile penetration	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Mobile subscribers	9,50	9,50	9,60	9,69	9,79	9,89	9,98	10,08	10,19	10,29
Market share	15,0%	15,5%	16,5%	17,7%	18,9%	20,1%	21,3%	22,5%	23,7%	24,9%
Subscribers million	1,43	1,47	1,58	1,72	1,85	1,99	2,13	2,27	2,41	2,56
ARPU		14	14	**13,5**	**13**	**12,5**	**12**	**11,5**	**11**	**10,5**
Revenues MEUR		20,62	22,16	23,16	24,05	**24,84**	**25,52**	**26,09**	**26,55**	**26,90**
Sites	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Additional sites				50	50	50	50	50	50	50
Total number of sites	2 000	2 000	2 000	2 050	2 100	2 150	2 200	2 250	2 300	2 350
Sectors per site	3	3	3	3	3	3	3	3	3	3
Spectrum MHz	40	40	40	40	40	40	40	40	40	40
Throughput bit/Hz	2	2	2	2	2	2	2	2	2	2
Capacity per site Mbit/s	240	240	240	240	240	240	240	240	240	240
Total capacity Mbps	480 000	480 000	480 000	492 000	504 000	516 000	528 000	540 000	552 000	564 000
Demand per user Mbps	0,02	0,03	0,10	0,11	0,12	0,13	0,14	0,16	0,17	0,19
Total demand Mbps	27 671	42 890	153 711	183 193	217 326	256 779	302 313	354 792	415 197	484 640
Utalization rate	6%	9%	32%	37%	43%	**50%**	**57%**	**66%**	**75%**	**86%**

Comments b)

But given that I missed to multiply the ARPU with 12 when I formulated the problem the total revenues implies an ARPU per month of EUR 1.17 in 2013, implying that ARPU per month would be negative after three years, which is impossible. However, some have based the answer on ARPU per year making it possible to solve the problem. Sorry for this and I will certainly take this into consideration when I go through and evaluate the exam.

	2014e	2015e	2016e	2017e	2018e	2019e	2020e
Revenues lower ARPU	23,16	24,05	24,84	25,52	26,09	26,55	26,90
Revenues base case	22,39	22,61	22,84	23,06	23,30	23,53	23,76
Deviation	0,77	1,44	2,00	2,46	2,80	3,03	3,13

c) In case the regulator decides to withdraw 20 MHz (1 January 2014) of the available 40 MHz that operator Edge is using how would that impact the investment plans and assuming that it goes for 25% market share by 2020 in line with what is express in a).
Is the initial investment plan sufficient when the spectrum holding is reduced with 50%? If not, how many new sites needs operator EDGE to deploy up until 2020 and how much capex would it be required to spend per year for the period 2014-2020? (1p)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country data										
population million	10	10	10,1	10,2	10,3	10,4	10,5	10,6	10,7	10,8
Mobile penetration	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Mobile subscribers	9,50	9,50	9,60	9,69	9,79	9,89	9,98	10,08	10,19	10,29
Market share	15,0%	15,5%	16,5%	17,7%	18,9%	20,1%	21,3%	22,5%	23,7%	24,9%
Subscribers million	1,43	1,47	1,58	1,72	1,85	1,99	2,13	2,27	2,41	2,56
ARPU		14	14	**13,5**	**13**	**12,5**	**12**	**11,5**	**11**	**10,5**
Revenues MEUR		20,62	22,16	23,16	24,05	**24,84**	**25,52**	**26,09**	**26,55**	**26,90**
Sites	2 000	2 000	2 000	2 000	2 050	2 100	2 150	2 200	2 250	2 300
Aditional sites base case				50	50	50	50	50	50	50
Total number of sites	2 000	2 000	2 000	2 050	2 100	2 150	2 200	2 250	2 300	2 350
Sectors per site	3	3	3	3	3	3	3	3	3	3
Spectrum MHz	40	40	40	**20**	**20**	**20**	**20**	**20**	**20**	**20**
Throughput bit/Hz	2	2	2	2	2	2	2	2	2	2
Capacity per site Mbit/s	240	240	240	120	120	120	120	120	120	120
Total capacity Mbps	480 000	480 000	480 000	246 000	252 000	258 000	264 000	270 000	276 000	282 000
Demand per user Mbps	0,02	0,03	0,10	0,11	0,12	0,13	0,14	0,16	0,17	0,19
Total demand Mbps	27 671	42 890	153 711	183 193	217 326	256 779	302 313	354 792	415 197	484 640
Utalization rate	6%	9%	32%	74%	86%	**99,5%**	**114,5%**	**131,4%**	**150,4%**	**171,9%**

Answer c)

The impact of reducing the available spectrum with 50% is that the current investment plan is not sufficient as the utilization rate is going above 100% as the table above show. Operator Edge has to deploy new sites.

The following table shows many sites Operator Edge has to deploy and how much it has to spend in capex to deploy the sites. In order to come under 100% I have added 10 extra sites per year. The estimated number of sites is the basis to calculate the annual capex for the upgrade. See below for the numbers.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country data										
population million	10	10	10,1	10,2	10,3	10,4	10,5	10,6	10,7	10,8
Mobile penetration	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Mobile subscribers	9,50	9,50	9,60	9,69	9,79	9,89	9,98	10,08	10,19	10,29
Market share	15,0%	15,5%	16,5%	17,7%	18,9%	20,1%	21,3%	22,5%	23,7%	24,9%
Subscribers million	1,43	1,47	1,58	1,72	1,85	1,99	2,13	2,27	2,41	2,56
ARPU		14	14	**13,5**	**13**	**12,5**	**12**	**11,5**	**11**	**10,5**
Revenues MEUR		20,62	22,16	23,16	24,05	**24,84**	**25,52**	**26,09**	**26,55**	**26,90**
Sites	2 000	2 000	2 000	2 000	2 050	2 100	2 150	2 529	2 967	3 470
Aditional sites base case				50	50	50	50	50	50	50
Total number of sites	2 000	2 000	2 000	2 050	2 100	2 150	2 200	2 579	3 017	3 520
Sectors per site	3	3	3	3	3	3	3	3	3	3
Spectrum MHz	40	40	40	**20**	**20**	**20**	**20**	**20**	**20**	**20**
Throughput bit/Hz	2	2	2	2	2	2	2	2	2	2
Capacity per site Mbit/s	240	240	240	120	120	120	120	120	120	120
Total capacity Mbps	480 000	480 000	480 000	246 000	252 000	258 000	264 000	309 513	361 992	422 397
Demand per user Mbps	0,02	0,03	0,10	0,11	0,12	0,13	0,14	0,16	0,17	0,19
Total demand Mbps	27 671	42 890	153 711	183 193	217 326	256 779	302 313	354 792	415 197	484 640
Utalization rate	6%	9%	32%	74%	86%	**99,5%**	**114,5%**	**114,6%**	**114,7%**	**114,7%**
Under capacity							38 313	45 279	53 205	62 243
Capacity per site							120	120	120	120
Requested number of extra sites							329	387	453	529
Total number of sites							2 529	2 967	3 470	4 049
Total capacity							303 513	355 992	416 397	485 840
Utalization rate							99,6%	99,7%	99,7%	99,8%
Extra sites							**329**	**387**	**453**	**529**
Capex										
New sites EUR							100 000	100 000	100 000	100 000
Radio equipment EUR							10 000	10 000	10 000	10 000
New sites MEUR							33	39	45	53
Radio equipment MEUR							3	4	5	5
Annual capex MEUR							**36**	**43**	**50**	**58**

Problem 3: Revenues and dimensioning of voice and data services (3p)

Background and problem

The year is 2008 and Operator BIG in a country has acquired the operator Small. Operator BIG gets access to another 5 MHz of spectrum in the 900 MHz band. Operator Small has used this frequency to offer cheap voice services to teenagers, master students and poor PhD students. The service offer includes up to 300 voice minutes per month for 10 € per month.

Now operator BIG consider to use this frequency band for other services and for business users. Two options are discussed at the marketing department of operator BIG
1) High quality voice services for 40 € per month
2) A new mobile data services called ATTA (All The Time Anywhere) for 60 € per month

These proposals are reviewed by the network planning and operation department in order to see what number of users that can be supported. Their main questions are the problems to solve for you at the exam. Motivate your answer and provide clear, complete and convincing explanations.
What are the revenues for the different services using the assumptions below?

Question a)

Will the high quality voice service generate higher revenues than the cheap voice service? (1,5 p)

Question b)

Will a data service as described below generate higher revenues than the cheap voice service? (1,5p)

Assumptions

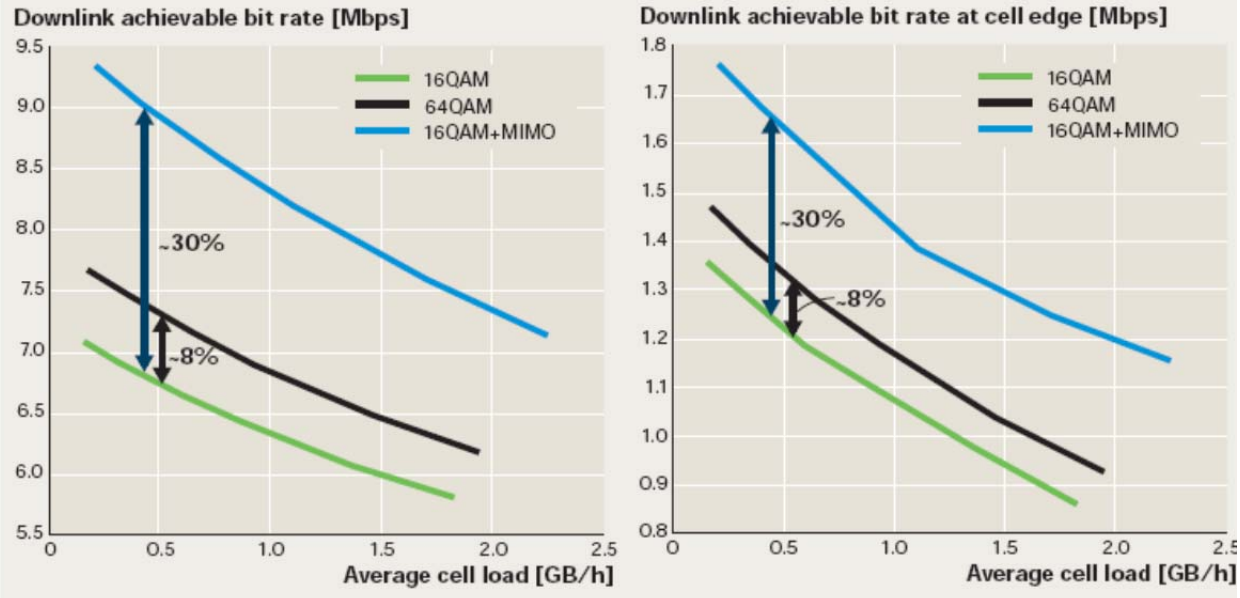
Demand and customer data:
Market research shows that there is still a big demand for the cheap voice service of 10 € per month, the market is estimated to be maximum 2 Million users. At the same time the market research predicts a large unmet demand from business users both when it comes to high quality voice services and mobile data services. This business market is estimated to be maximum 0,3 Million users.

User profile data:
The high quality voice service includes 3000 minutes per month. For dimensioning it is assumed that each user generates 100 mE during busy hour and that the blocking rate is 0,01%.
The cheap voice service includes 300 minutes per month. For dimensioning it is assumed that each user generates 50 mE during busy hour and that the blocking rate is 1%. Erlang table is attached.
For the new data service monthly buckets of 3,6 GB are offered. For dimensioning it is assumed that the data is used 20 days per month during 8 hours of the day (all equally busy).

Network data:
Operator BIG will reuse the network of operator small consisting of 500 three sector sites in urban areas. The voice service make use of 4,8 MHz and existing GSM base stations with reuse factor 3. (The GSM system has 200 kHz carriers, assume 8 time slots, i.e. voice channels, for all carriers)

For the mobile data services the network department has seen results to be published the next year in Ericsson review. The article presents achievable bit rates for different levels of cell load for “new” releases of HSDPA (i.e. with system bandwidth 5 MHz). Using Figure 4 from the article the network experts make an estimate of the cell throughput and the number of users that can be served. Assume three sector system and a reuse factor of 1.

FIGURE 4 HSPA Evolution downlink bit rate over the area at 5 percent (low traffic volume) to 70 percent utilization (high traffic volume). Left: Average. Right: 10th percentile.



Solution problem 3:

General

In this problem there are two different aspects to be considered:
1. To see how many users that can be supported for different services
2. To compare the number of supported users to the expected demand

For voice services we have 4,8 MHz, i.e.in total 24 carriers. With re-use 3 that means 8 carriers per sector, 8 carriers have 64 voice channels. Blocking is computed per sector and site capacity is for all three sectors.

Cheap voice service

With 1% blocking 50,6 Erlang can be supported per sector, this corresponds to 1012 users (each generating 50 mE) and 3036 users per sites. For 500 sites this means 1 518 000 users. Hence, less number of users (~1,5 M) can be supported compared to the max demand (2 M).

High quality voice

With 0,01% blocking 39,78 Erlang can be supported per sector, this corresponds to 398 users (each generating 100 mE) and 1194 users per sites. For 500 sites this means 598 000 users. Hence, more users (~0,6 M) can be supported compared to the demand (0,3 M)

Data service

Here we use average throughput per user and compare with the site capacity. We know that we have 5 MHz but no numbers are given for spectral efficiency, this has to be derived from the figure from Ericsson Review. The figure shows “achievable bit rate” as function of cell load expressed as GB per hour. The figure may be difficult to interpret but “achievable bit rate” means the highest bit rate that can be observed, the figure shows cell averages and cell border results. The curves do not give any clue on average bit rate or spectral efficiency.

However, the results is presented as function of cell load, from 0 up to ~2,5 GB/hour.
This is used as input for capacity estimation. You can use a number around 2,25 GB/hour (max shown in figure) corresponding to 5 Mbps. Alternatively you can use the info that the figure shows results up to 70% of max load, that means that around 2 GB/hour corresponds to 70% of max cell capacity, hence max cell capacity would be 6,5-7 Mbps.
Using 5 Mbps the site capacity is 15 Mbps (or 19 Mbps using the 70% assumption).
The users generate 25 kbps which means that each site can support 600 users (760).
For all 500 sites this means 300 000 users – exactly the estimated max demand!

Revenues

Use min {Max demand; No supported users} and compute revenues and see what service that generates highest revenues, this give the answers on questions a) and b).

Service	max demand	No supported user	paying users	revenues
cheap voice	2000000	~1500000	1500000	15 M€
Quality voice	300000	~600000	300000	12 M€
Mobile data	300000	300000	300000	18 M€

Problem 4: Mobile services and business models (3p)

The Osterwalder canvas is often used to provide an overview of the business model aspects for mobile services. In this problem you should fill in relevant elements in the canvas (skip cost and revenues) for different mobile services. The value proposition of services in all cases targets end-users (consumers).

Question a)

Consider a mobile operator that offers mobile broadband services for smartphones. Use the canvas in order to show what can be good strategies in order to offer a very competitive offer. Use examples from your HW country or some of the countries you have reviewed (1p)

Question b)

Fill in the relevant elements in the Osterwalder canvas (skip cost and revenues) for the Mobile health service described in Appendix A, highlight what actor that provides the service to the end-user (1p).

Question c)

Fill in the relevant elements in the Osterwalder canvas (skip cost and revenues) for the connected car service described in Appendix B, highlight what actor that provides the service to the end-user (1p).

Solution problem 4:

General:

The canvas should include the following aspects:

- customer aspects, i.e. segments (to whom) and value proposition (what is offered, benefit)
- activities and resources, what is needed, what is done and by whom
- partner , who else is involved? Who else provides resources and activities

The key starting point for the analysis is that it should be clear what actor that provides the service and has the main customer relation. In case a) it is the mobile operator but in cases b) and c) the situation is different.

If the service provider is not correct the content filled in in the canvas is not relevant!!

Question a)

Here the Mobile operator offers services to consumers.

The “connectivity offer” can be improved by including phones, music or media services

Question b)

The mobile service is part of a healthcare services offered by hospitals (or by some other type healthcare provider). AT&T and Ericsson are partners where AT&T is the one that has the agreement with the hospital for providing the service, Ericsson provides the service platform and operates the platform.

Question c)

In this case Volvo provides services to the car drivers/owners. Ericsson provides the service platform (in the Volvo case also connectivity agreements). In the general case the car company or Ericsson can operate the service platform.

Problem 5: Telecom markets, operator network and spectrum strategy

This problem includes a lot of information, the challenge is to see what is important - and not! You need to consider what kind of analysis that can be made based on the available data.

Background – spectrum availability

Future demand for more capacity can be met by allocation of more bandwidth and new spectrum bands to mobile communication. But spectrum is a scarce resource and allocation of new licensed bands will only partly satisfy the growing demand. The take-off for mobile broadband underscores the essential role spectrum plays for operators, as it enables operators to provide coverage and capacity in their mobile networks.

However, the conditions for the operators varies considerable as operators in Pakistan and India in average have access to just around 2 x 15 MHz while operators in Germany and Sweden in average have access to 2 x 70 MHz, see figure 1.

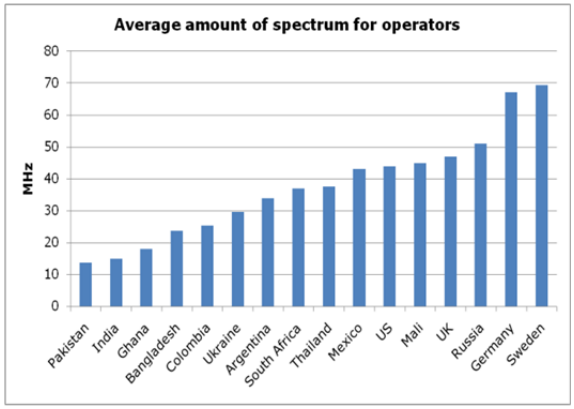


Figure 1 Average amount of spectrum for mobile operators in different countries (compilation of data by B.G. Mölleryd)

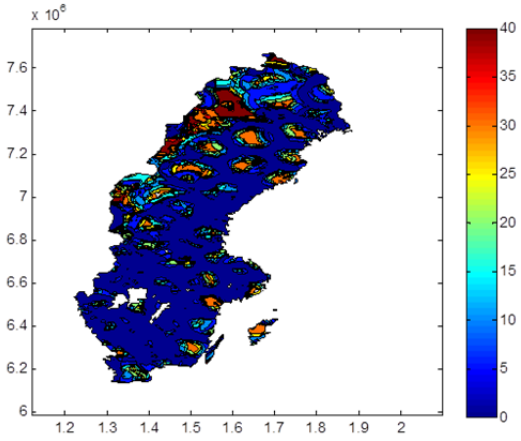


Figure 2 Example of spectrum availability the number of available TV channels in Sweden (from Quasar deliverableD5.1)

Background – Secondary access of spectrum

Another possibility besides licensing of new bands is called secondary access of spectrum bands. This means that bands that primarily have been allocated for other services, e.g. TV or traffic control radars are used by a "secondary user" e.g. a mobile operator. . The secondary use exploits un-used spectrum in frequency, time or physical location. Such un-used spectrum in the TV bands is called TV white space (TV WS).

An example of TV WS spectrum availability is shown in Figure 2. The number of "un-used" TV channels is very low in most part the country. "Many" TV channels are available in rural areas in northern Sweden, areas where the population density (and demand) is low. Please note that the availability of spectrum for secondary use depends on the type of services and the type of network deployment that is used. If TV white space is to be used for mobile broadband access there is a difference how it can be used depending on how the mobile broadband network is deployed. By using macro base stations with high towers the mobile broadband services will cause interference over large distances, hence the spectrum availability is low.
Drivers for secondary use of spectrum can be:

- that an operator has not got (bought) licensed spectrum,
- that it is cheaper to re-use sites using TV WS than deployment of new sites
- licensed spectrum is too expensive (see next page)

Background – Price for spectrum

It is sometimes claimed that one driver for secondary use of spectrum is that the cost of spectrum can be avoided. However, this is only partly true since it depends on the paid spectrum price in relation to other network costs. Consider the prices paid at recent spectrum auctions in different countries. Using the metric "spectrum price normalized to number of MHz and the population", we can identify large differences between auctions in different countries, see Figure 3.

The Swedish operators in average paid EUR 0.68 per MHz/pop for the 800 MHz band, while prices for spectrum in the 2.6 GHz band reached EUR 0.30 per MHz/pop in Sweden, EUR 0.05 in Germany and just 0.01 in the Netherlands. Interestingly enough, prices paid at the Indian 3G auction in 2010 for spectrum in the main two cities are not far off from the very high prices paid at the 3G auctions in the years 2000-2001.

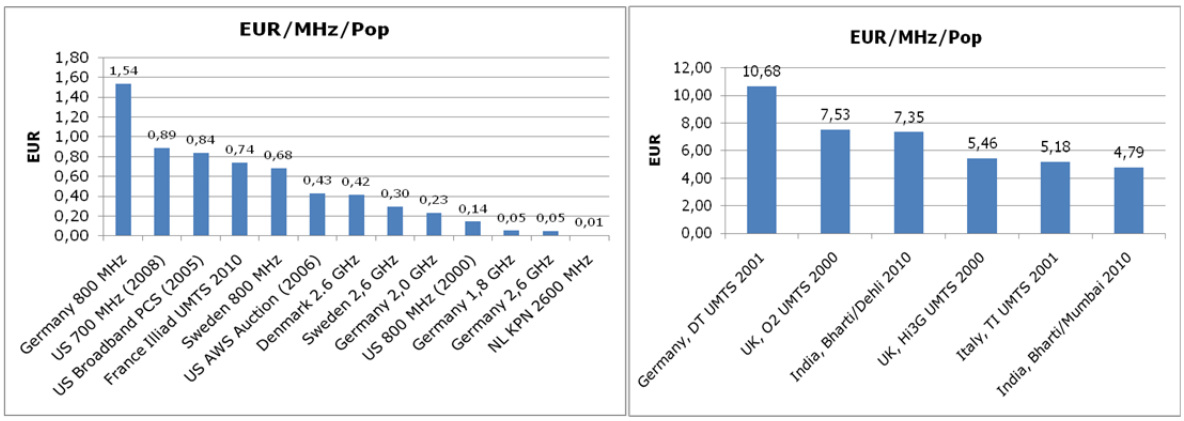


Figure 3 Prices paid per MHz/Pop in spectrum auctions and for 3G licenses in India and Europe

The problem to solve (3p)

Consider the four generic cases of rural and urban mobile broadband deployment in a Nordic country and in India respectively. Taking into account the total amount of spectrum and other available information in the table below your task is to identify the deployment case (cases) where use of TV white space would be worthwhile to investigate more - motivate your answer.

Assumptions

Assume three sector sites and an average cell spectral efficiency of 0,67 bps per Hz for rural and 1,67 bps for urban deployment. The operators have existing GSM sites that can be re-used for mobile band deployment, the coverage areas are indicated in table 1.

A TV channel is assumed to have an efficient bandwidth of 7 MHz.

The data consumption is distributed equally over 8 hours per day 30 days per month.

Deployment case	Number of operators	Bandwidth per operator	Spectrum price € /MHz/pop	No available TV channels	Max No users /km2	Demand Per user	Coverage per site
Nordic Urban	4	40 MHz	~0,10	0 – 5	2 000	5,4 GB/month	0,4 km2
Nordic Rural	4	10 MHz	~0,50	15 – 20	20	5,4 GB/month	100 km2
India Urban	8	5 MHz	~5	0 – 10	10 000	2,7 GB/month	0,2 km2
India Rural	6	5 MHz	~1	10 - 15	400	1,4 GB/month	50 km2

Table 1. Deployment cases to compare

Solution problem 5:

Approach

This problem includes a lot of information, the challenge is to see what is important and not - and what kind of analysis that can be made based on the available data.

1. Start to look what kind of data and information that is available – and not!
    a. There are no ARPU figures -> hence we cannot estimate any revenues.

    b. There is no information about the total spectrum cost for the operators, the number of sites or the cost structure in terms of sites, radio, transmission -> we have no clue about spectrum costs related to other costs

    c. There are no performance or cost figures for solutions using TVWS -> we cannot make any comparative analysis

2. The information we have are *total* user demand and network capacity expressed per area unit (Mbps per km2) =>*Estimate total demand and supplied capacity* and see what can be learned from comparison of these numbers for the different cases. Check in what cases can we see a clear shortage of capacity (spectrum)?

Calculations

Deployment case	Total available bandwidth	Site capacity (Mbps) using all spectrum	Capacity per km2	Demand per km2	Supply vs demand
Nordic Urban	4*40 = 160 MHz	1.67*3*160 =800	2000 Mbps	100 Mbps	S >> D
Nordic Rural	4*10 = 40 MHz	0.67*3*40 = 80	0,80 Mbps	1,0 Mbps	S ~ D
India Urban	8*5= 40 MHz	1.67*3*40 = 200	1000 Mbps	250 Mbps	S >> D
India Rural	6*5= 30 MHz	0.67*3*30= 60	1,20 Mbps	10 Mbps	S << D

Table 1. Deployment cases to compare with solution guideline

Conclusions

We can see that for the urban cases the total supplied capacity is much larger than the demand. For these cases there is no lack of capacity or spectrum. The same is true for the rural case in Sweden where the demand is roughly the same as the offered capacity. In case more capacity really is needed, some additional sites can be added.

However, for the case of rural deployment in India the demand is much higher than the offered capacity. Hence, this would be a case to investigate further for use of TV WS.
In addition, the situation in India is characterized by: i) low amount of licensed spectrum allocated to operators (figure 1), and ii) high spectrum prices (figure 3).