OPTA's fixed and mobile bottom-up long-run incremental cost models

Additional network design flow diagrams

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analysys mason

Contents

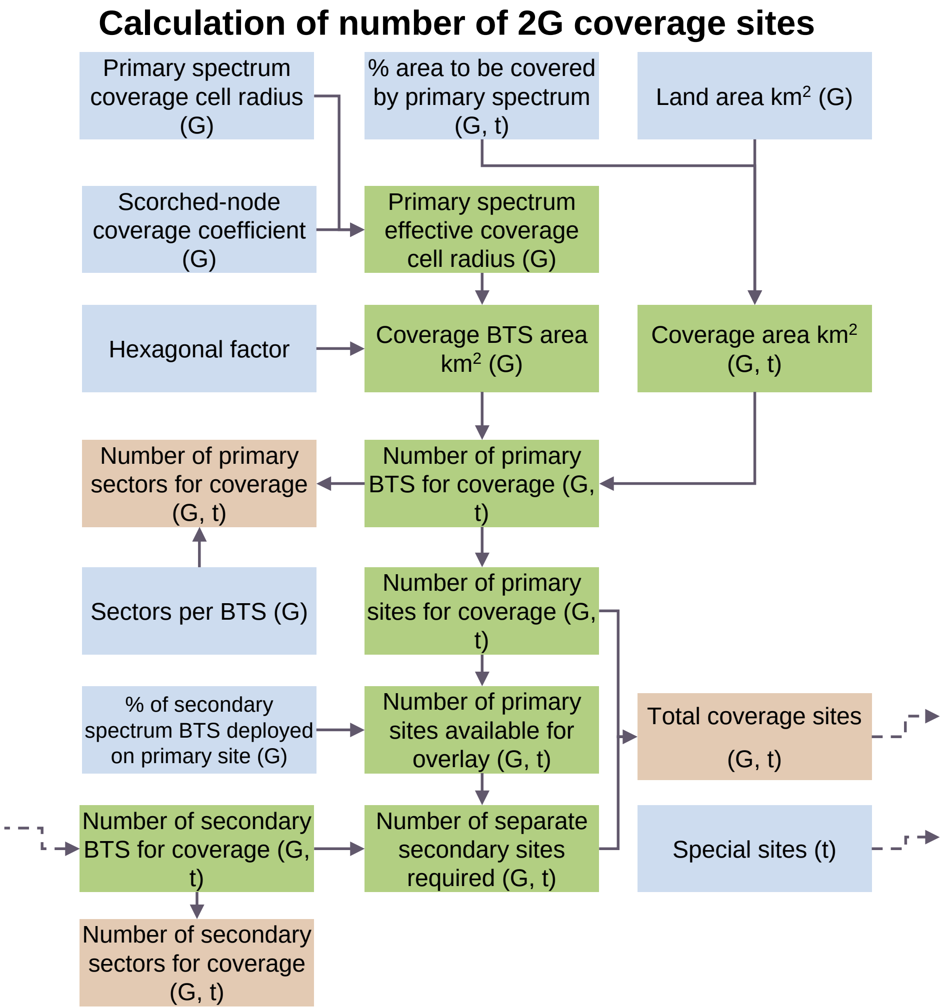
Key

Input

Calculation

Output

2G sites deployed for coverage

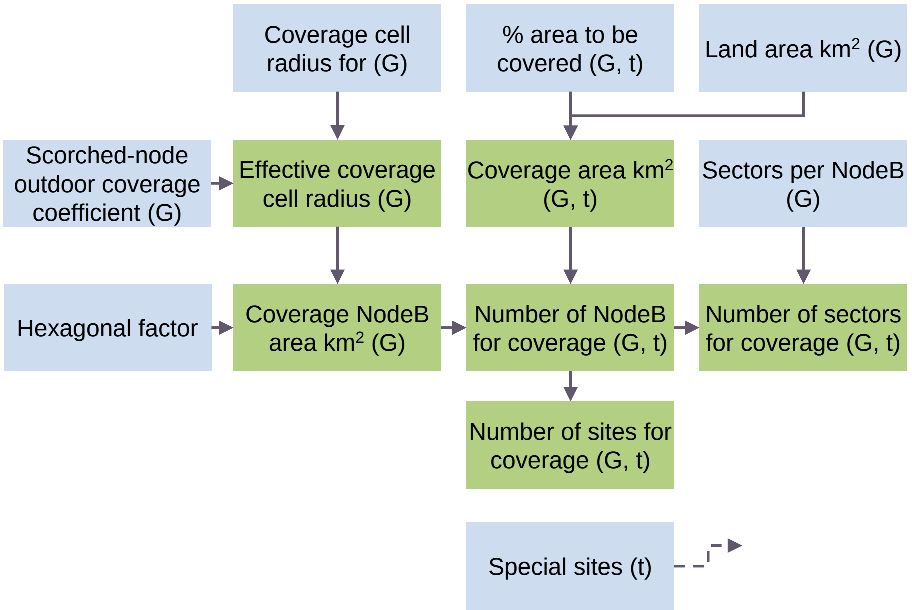


G = by geotype, t = by time

- The coverage networks for each frequency band (primary GSM, secondary GSM) are calculated separately within the model
- The coverage sites for the primary spectrum are calculated first:
  - the area covered by a BTS in a particular geotype is calculated using the effective BTS radius
  - A scorched-node coverage coefficient (SNOCC) is used to account for practical limitations in deploying sites resulting in sub-optimal locations
  - total area covered in the geotype is divided by this BTS area to determine the number of primary coverage BTSs required
- The calculation of the number of secondary coverage BTSs includes an assumption regarding the proportion of secondary BTSs that are overlaid on the primary sites
- Special indoor sites are modelled as an estimate based on data provided by the operators.

3G sites deployed for coverage

Calculation of number of 3G coverage sites



- The same methodology is used to derive the initial number of coverage NodeBs required for UMTS
- The model calculates site sharing between GSM and UMTS networks, and new standalone 3G sites required:
  - the proportion of 3G sites which are deployed on standalone sites is based on Antennebureau data
  - there must be sufficient 2G sites available to host the shared 3G sites (otherwise additional 3G standalone sites will be deployed)
- Special indoor sites are modelled as an estimate based on data provided by the operators.
- UMTS network is an overlay network and does not need to fill every gap of coverage. As a result, its SNOCCs may be higher than the corresponding GSM SNOCCs

Sheet: Network_design, Rows 649-669

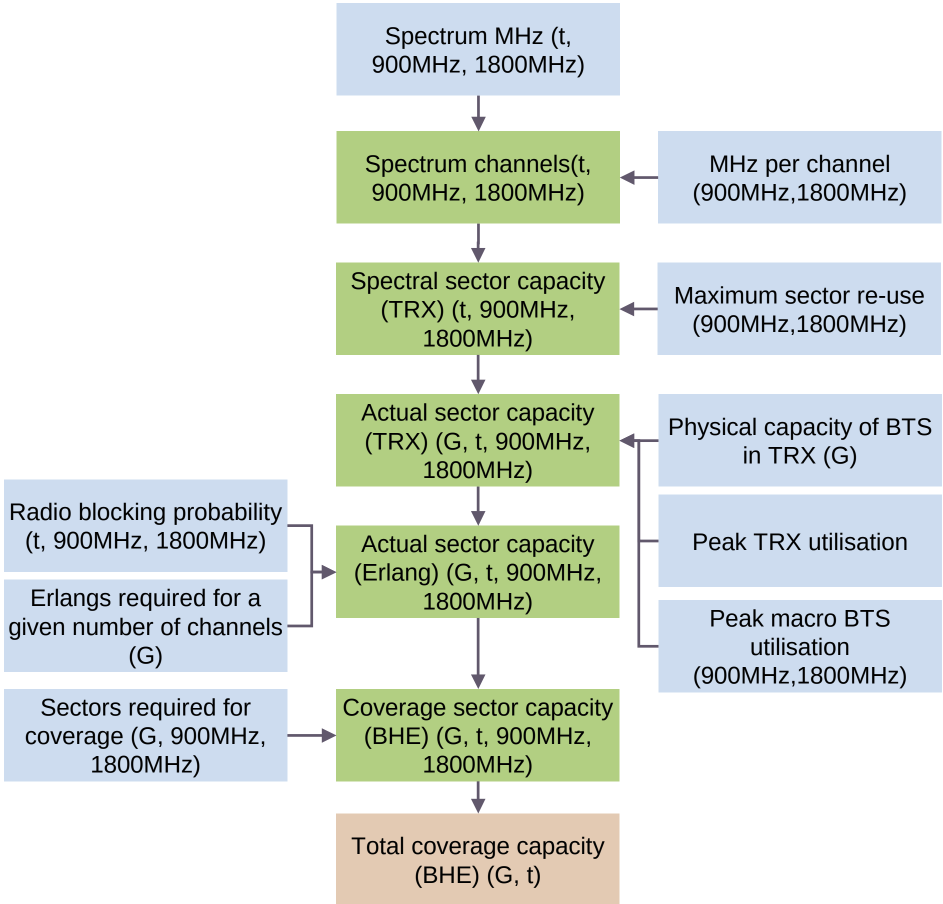
GSM capacity calculations

- Further inputs to the radio network bottom-up algorithm include:
  - blocking probability 2%
  - amount of paired spectrum available to each operator
  - maximum reuse factor of 16 (sectors)
  - minimum and maximum TRX per sector
  - number of reserved GPRS channels per sector
  - number of signalling channels per TRX
- Calculated TCH requirement in the model is driven by voice Erlang load:
  - SMS assumed to be carried in the signalling channels
  - GPRS in the busy hour assumed to be confined to the GPRS reservation

Sheet: Network_design_Inputs, Rows 209, 236-254 Sheet: control, Rows 8-9

Capacity provided by 2G coverage sites

Calculation of the BHE capacity provided by the coverage network

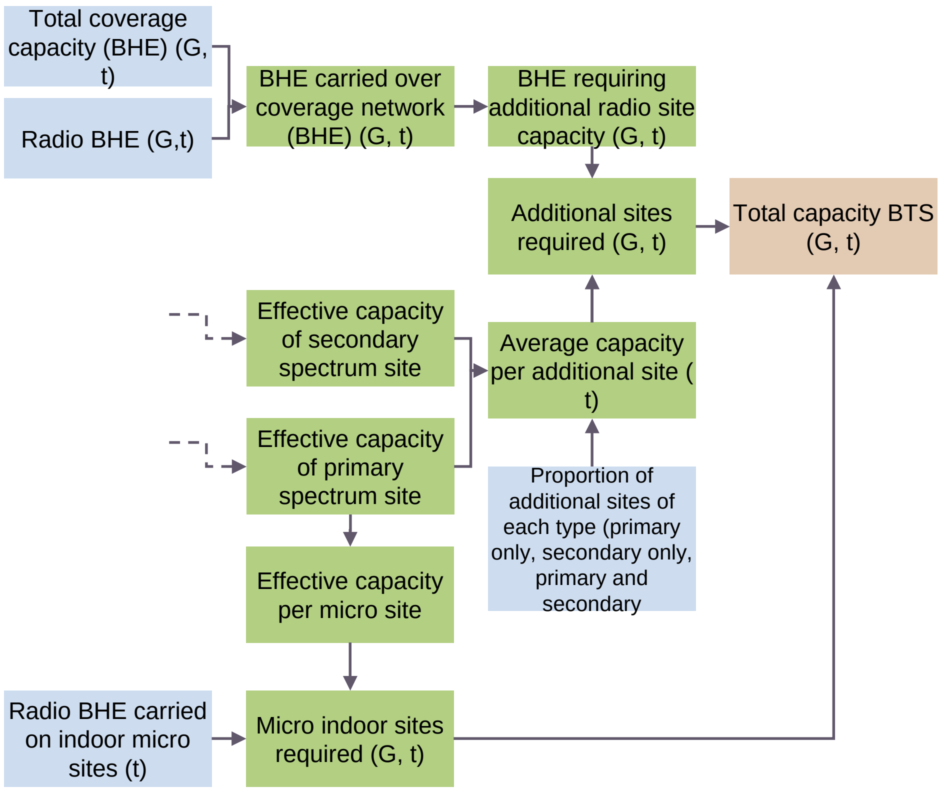


- Calculating the capacity provided by the coverage sites is the first step:
  - capacity for each frequency band is calculated separately
- The spectral limit per sector is the number of transceivers that can be deployed per sector, given a certain maximum spectrum re-use factor:
  - the lesser of the physical capacity and the spectral capacity of a sector is the applied capacity
- The sector capacity in Erlangs is obtained using the Erlang B conversion table and then multiplied by the total number of sectors in the coverage network to arrive at the total capacity of the coverage network:
  - in calculating the effective capacity of each sector in the coverage network, allowance is made for the fact that BTSs and TRXs will be *on average* **less than 100%** loaded for the network busy hour
  - we also exclude signalling and reserved GPRS channels from the Erlang capacity

Sheet: Network_Design, Rows 108–179

Additional 2G sites deployed for capacity

Calculation of the additional 2G sites required to fulfil capacity requirements

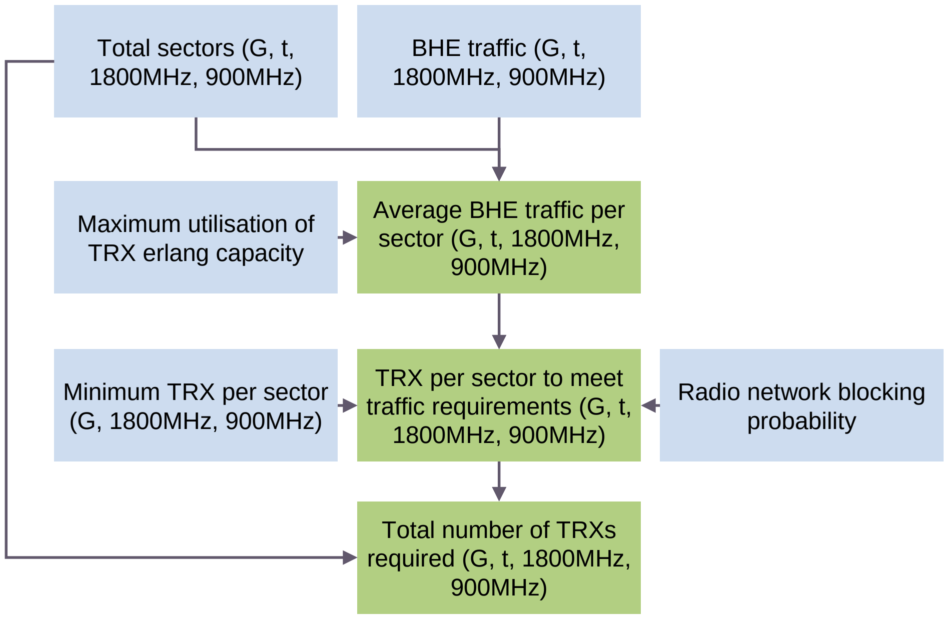


- Additional sites required are calculated to fulfil capacity requirements after the calculation of the capacity of the coverage networks
- Three types of GSM sites are dimensioned according to the spectrum employed: primary-only sites, secondary-only sites and dual sites
  - we currently assume that all additional sites are dual-spectrum (900MHz plus 1800MHz overlaid)
  - these parameters are used with the effective BTS capacities to calculate the weighted average capacity per additional site by geotype
- The total BHE demand not accommodated by the coverage networks is then used, along with this weighted average capacity, to calculate the number of additional sites required to accommodate this remaining BHE
- Micro indoor sites are modelled as an additional layer of omni-sector primary spectrum capacity sites

Sheet: Network_Design, Rows 175–201

TRX requirements

Calculation of transceiver deployment

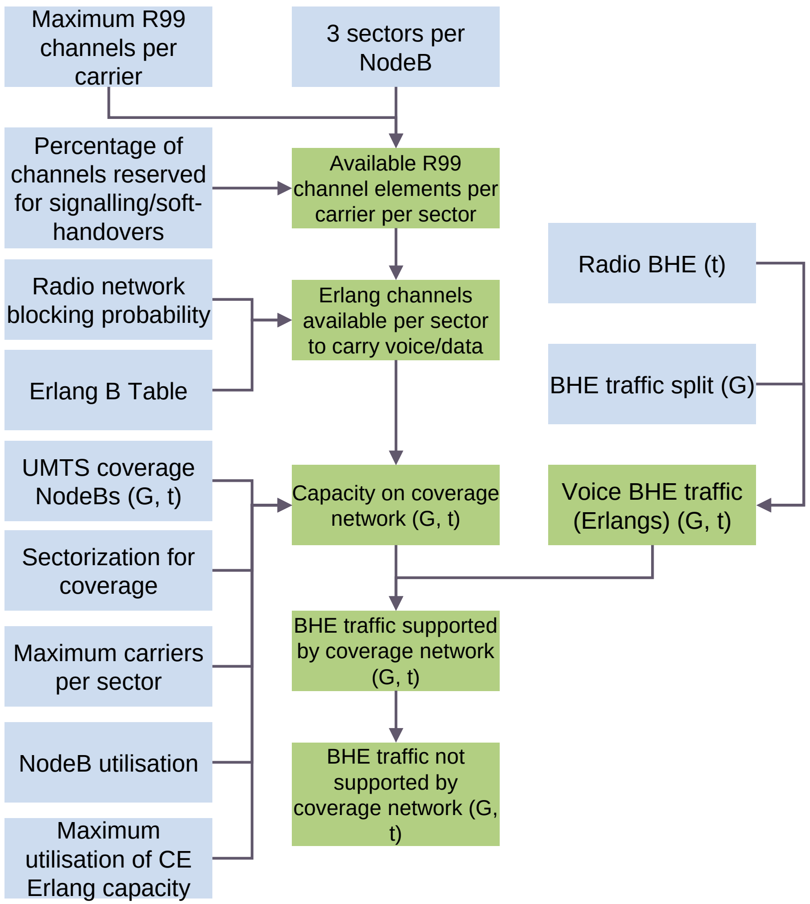


- The number of TRXs required in each sector (on average, by geotype) to meet the demand is calculated:
  - taking into consideration the maximum TRX utilisation percentage
  - converting the Erlang demand per sector into a channel requirement using the Erlang-B table and the assumed blocking probability
  - excluding signalling and GPRS channel reservations
  - assuming a minimum number of 1 or 2 TRXs per sector
- The total number of TRXs required is obtained by multiplying the number of sectors and the number of TRXs per sector

Sheet: Network_Design, Rows 325–449

Capacity provided by 3G coverage sites

Calculation of the BHE capacity provided by the UMTS coverage network

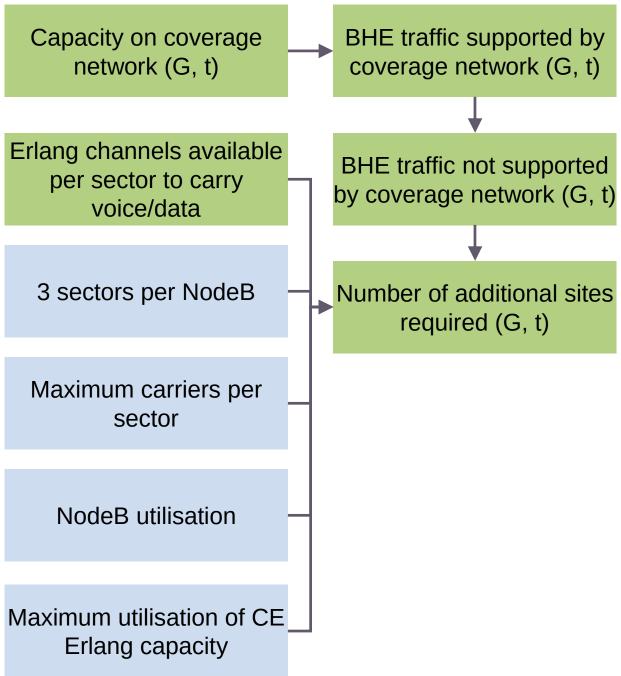


Sheet: Network_design, Rows 671-721

- Calculating the capacity provided by the 3G coverage sites is the first step in the calculation of the capacity requirements
- The model assumes a maximum number of Release 99 channel elements per Node B:
  - the available channel elements per carrier are *pooled* between the three sectors of the Node B after taking into account the soft-handover reservations
  - the sector capacity in Erlangs is obtained using the Erlang-B conversion table and the number of channel elements per sector
- The sector capacity in Erlangs is multiplied by the total number of UMTS sectors in the coverage network to arrive at the total capacity of the network:
  - the maximum deployment of carriers per sector, subject to the average utilisation factor less than 100%, is assumed on all coverage sites
  - in calculating the effective capacity of each sector in the coverage network, allowance is made for the fact that NodeBs and channel elements will in fact be less than 100% utilised on average during the network busy hour
- Special indoor sites are assumed to provide additional capacity as if they were an omni-sector site

Additional 3G sites deployed for capacity

Calculation of the additional 3G sites required to fulfil capacity requirements

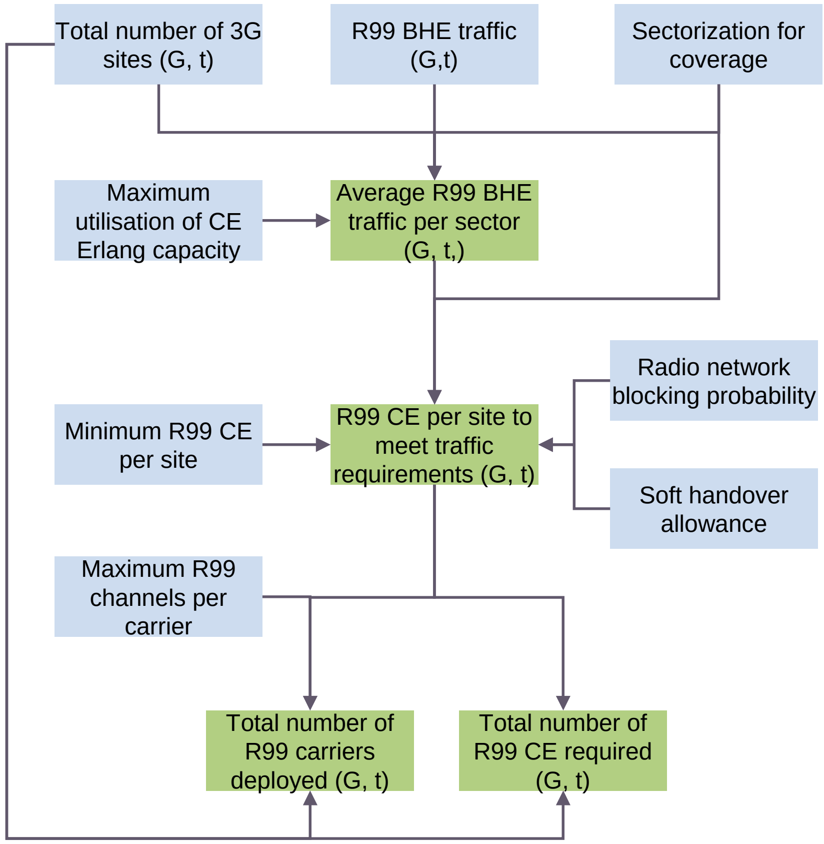


- Additional sites required are calculated to fulfil capacity requirements after the calculation of the capacity of the coverage network
  - BHE that cannot be accommodated by the coverage network by geotype is calculated
  - the calculation of the capacity of the additional sites assumes the deployment of carriers per sector subject to the average utilisation factor
- Micro indoor sites are modelled as an additional layer of mono-sector capacity sites
- It should be noted that the 3G coverage network has significant capacity (having been implicitly designed to cope with up to 50% load for cell breathing purposes) therefore additional sites for capacity are only calculated in extremely high traffic situations

Sheet: Network_Design, Rows 722-726

Channel element and carrier requirements

Calculation of R99 channel kit and carrier dimensioning

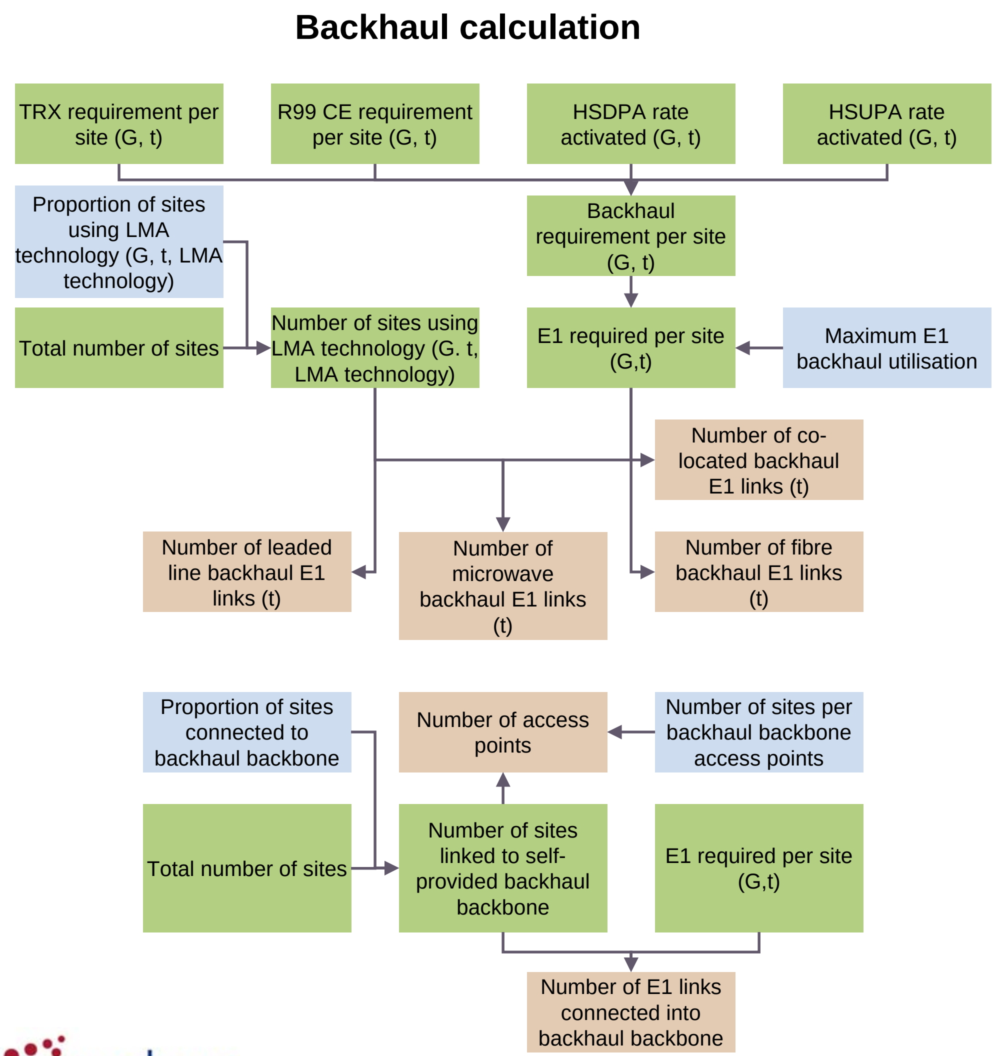


- The dimensioning of R99 channel elements (CEs) is done in a similar manner to the calculation of 2G TRXs, with the exception that an allowance is made for soft handover:
  - the number of R99 carriers for each site is then calculated, based on the maximum number of R99 channel elements per carrier
- Additional CEs for high-speed data services are dimensioned based on:
  - configuration profiles for the various high-speed data services technologies i.e. number of CEs per NodeB for HSDPA 1.8, etc.
  - activation profiles by year and geotype
- The total number of CEs required is obtained by multiplying the number of sites and the number of CEs per site:
  - this is repeated for carriers and for each type of CEs (R99, HSDPA, HSUPA)

We have split the transmission network into three parts

- National backbone based on leased dark fibre
  - connects the eight major cities: Amsterdam, Rotterdam, Arnhem,Tilburg, Utrecht, ‘s Gravenhage, ‘s Hertogenbosch and Breda
  - is used to carry inter-switch voice traffic, VMS traffic and data traffic to the internet
- Regional backbones based on leased dark fibre
  - connect the eight major cities on the national ring with the rest of the country
  - used to carry backhaul transit i.e. traffic between BSC/RNC and transmission access point
  - used to carry BSC-MSC and PCU-SGSN traffic for remote BSCs
- Last-mile access (LMA) network based on leased lines, microwave, or fibre:
  - used to collect traffic from BTS/Node B to nearest BSC/RNC or transmission access point
  - some sites are co-located at switch of fibre access point
- Additional rules:
  - indoor sites always linked with leased E1
  - microwave not used in urban areas ***due to line-of-sight difficulties***
  - fibre links not used in rural areas ***due to distance***

Dimensioning the backhaul network



Sheet: Nw_Des, Rows 451-557, 938-1057

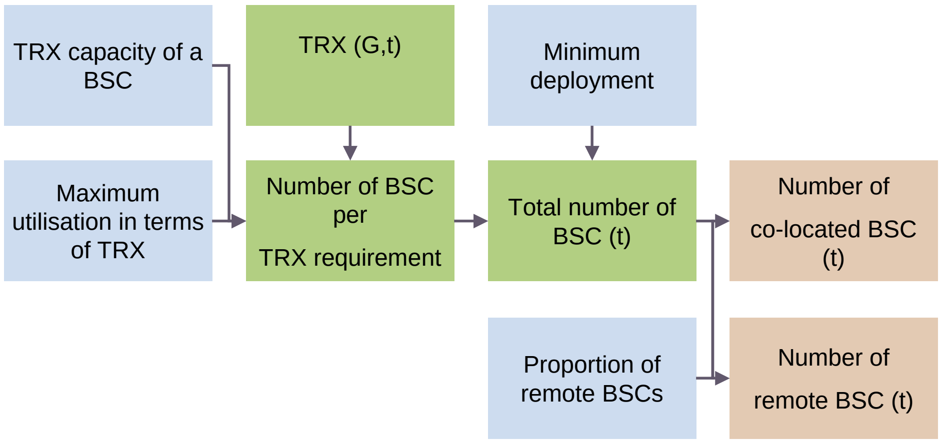
- First, the backhaul capacity required by site is calculated:
  - TRXs and R99 CEs drive the number of voice and GPRS/EDGE channels requiring backhaul
  - HSDPA/HSUPA backhaul need is directly derived from the active headline rate e.g. 7.2Mbit/s
- Backhaul traffic is then allocated to the various last-mile access (LMA) technologies:
  - the distribution of LMA technologies is an input to the model
  - the number of E1s required per site (on average) is different in each geotype but does not vary with the LMA technology used
- Finally, each part of the backhaul network is dimensioned:
  - microwave E1s are converted into microwave links (32Mbit/s equivalents)
  - leased-line E1s are identified separately by geotype as their price is distance-dependent
- A defined proportion of sites are assumed to require backhaul transit on the regional backbones

Dimensioning the backbone network

- First, the model summarizes all traffic types to be carried over the backbone networks:
  - fibre backhaul last-mile access (LMA)
  - backhaul transit
  - BSC–MSC, PCU-SGSN and RNC–MSC links when not co-located
  - MSC inter-switch and VMS access links when not co-located
- Traffic types are then allocated to the national and regional backbones
- Finally each backbone network is dimensioned:
  - the number of access points is calculated (directly from a model input for the national backbones and based on geo-analysis for the regional backbones)
  - the capability of the backbone access points e.g. STM1, STM4, etc. is based on the total traffic carried by the backbone
  - the fibre distance is calculated
  - for the regional backbones, model inputs are used to allocate the total traffic to be carried to each individual backbone e.g. share of BSC–MSC and RNC–MSC links
- A simpler model is used for NGN transmission:
  - it is assumed that all national access points have 10 GbE capability
  - at the regional level, STM64 access points have 10GbE capability; STM16 access points have 2x1Gb capability, and the remainder (STM1, STM4) have 1GbE capability
  - the same fibre distances are used as in the above case

BSC unit deployment

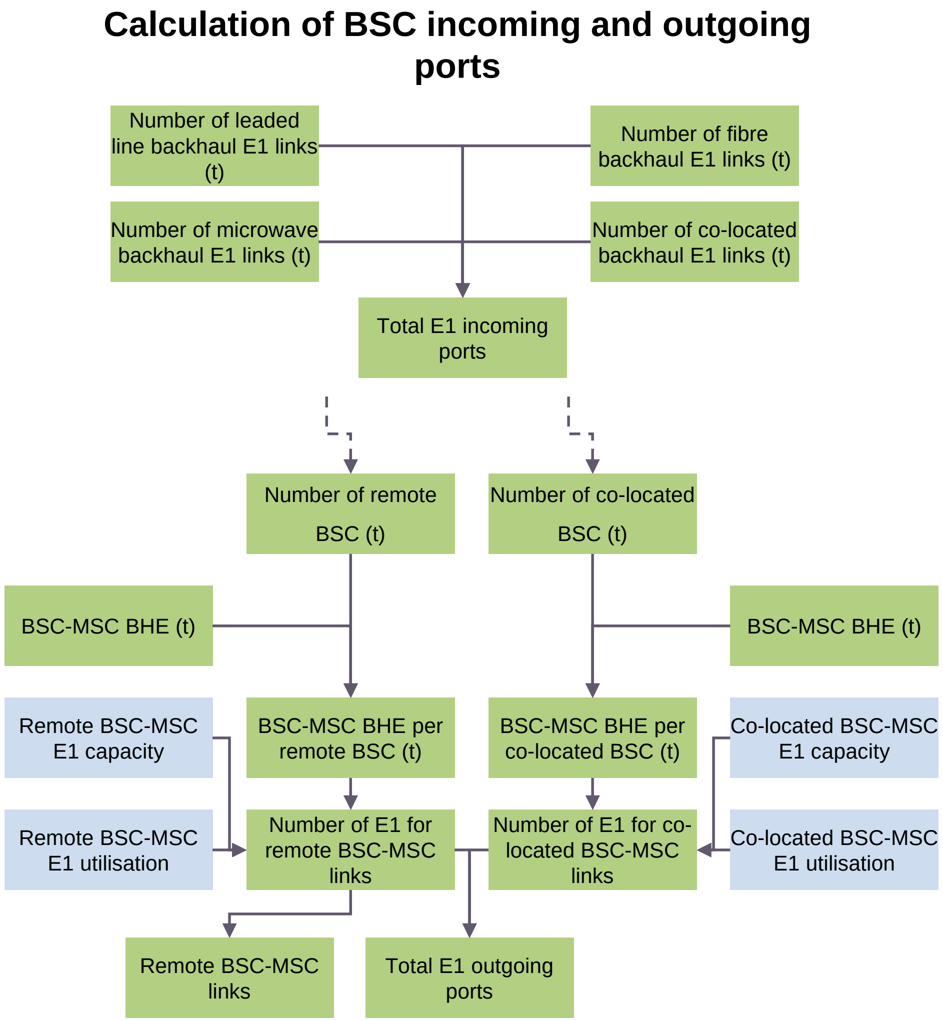
Calculation of BSC deployment



- BSC unit deployment is driven by two requirements:
  - maximum number of TRXs controlled, assuming a maximum utilisation
  - minimum number of 13 BSCs deployed in the network (for redundancy)
- Each of those two requirements leads to a different number of BSC units:
  - the total number of BSCs corresponds to the higher of those two values
- A proportion of BSCs are designated as ‘remote’ (i.e. not co-located with an MSC)

Sheet: Network_design, Rows 560–587

BSC incoming and outgoing ports and transmission requirements

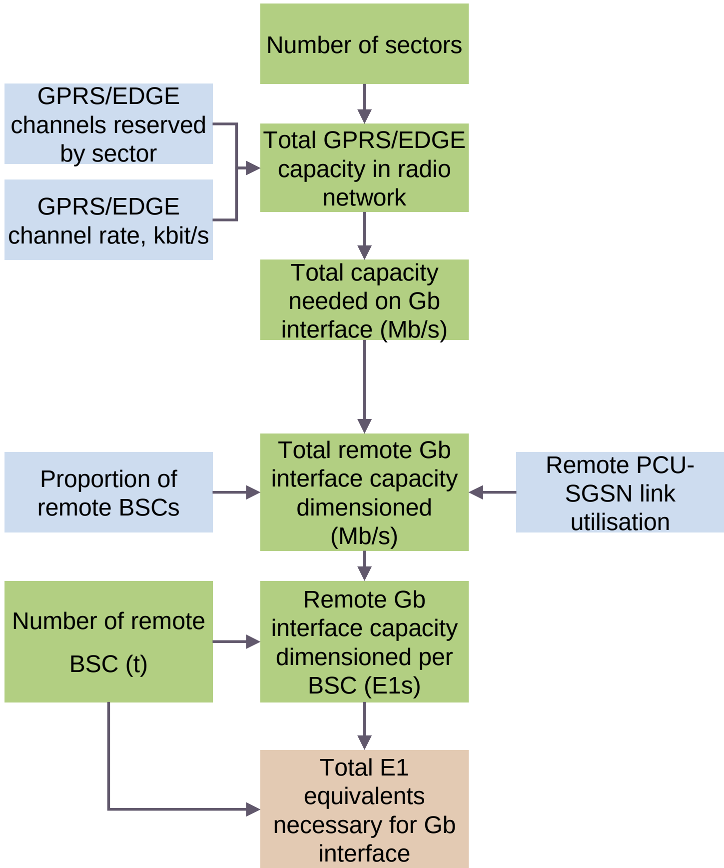


- BSC incoming ports (ports facing BTS) are directly derived from the number of backhaul E1 links, all technologies included
- Remote BSC–MSC traffic is first calculated as a proportion of total BSC–MSC traffic (based on the proportion of remote BSCs) and then dimensioned taking into account the capacity and utilisation of remote BSC–MSC links
- Co-located BSC–MSC traffic is first calculated as a proportion of total BSC–MSC traffic (based on the proportion of co-located BSCs) and then dimensioned taking into account the capacity and utilisation of co-located links
- Total BSC outgoing ports include both the remote and co-located links
- BSC–MSC transmission requirements correspond only to remote BSCs:
  - this number is expressed either in E1 or STM1 equivalents depending on the capacity needed

Sheet: Network_design, Rows 589-597, 615-646

PCU-SGSN link dimensioning

Calculation of PCU-SGSN links (Gb interface)

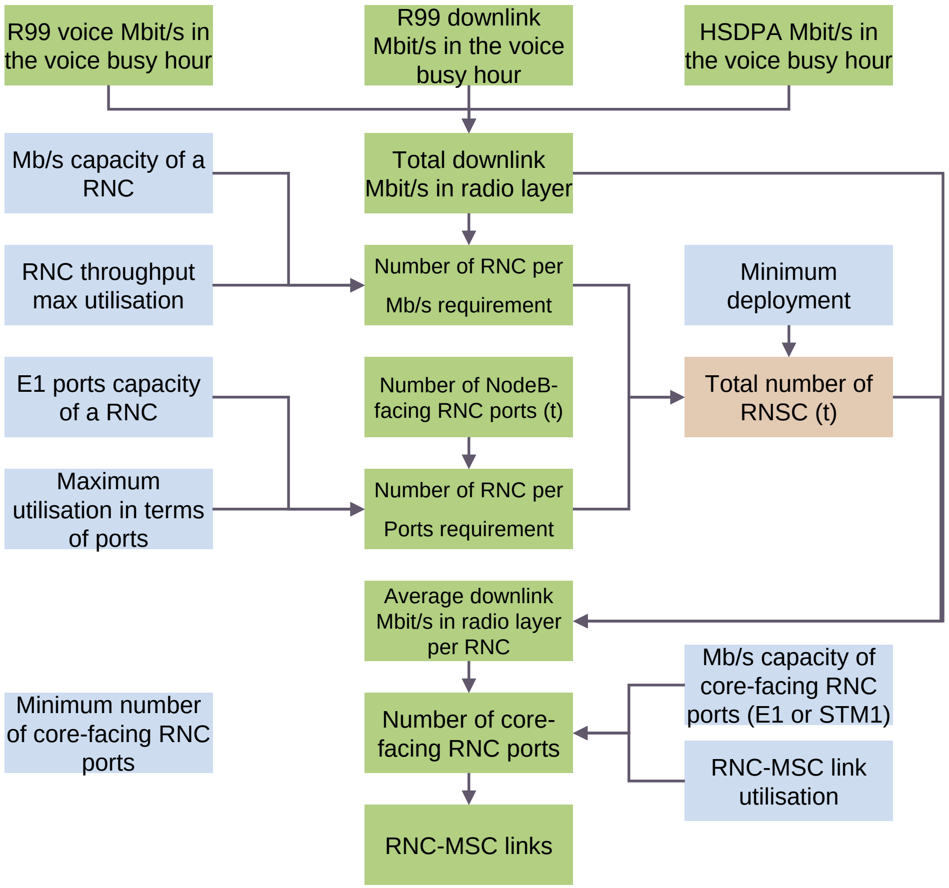


- First, the Gb interface (PCU-SGSN links) is dimensioned in order not to be the network bottleneck
  - capacity needed on the Gb interface is assumed to be equal to the capacity that would be needed if all GPRS channels reserved were simultaneously active on all sectors in the network
- Second, remote Gb traffic is calculated as a proportion of total PCU-SGSN traffic
  - based on the proportion of remote PCUs assumed to be equal to the proportion of remote BSCs
- Remote Gb traffic is then converted into E1 equivalent taking into account the utilisation of remote PCU-SGSN links
- Finally Gb links are added to the BSC-MSC links for the purpose of expressing either in E1 or STM1 equivalents depending on the capacity needed

Sheet: Network_design, Rows 602–613

RNC unit deployment

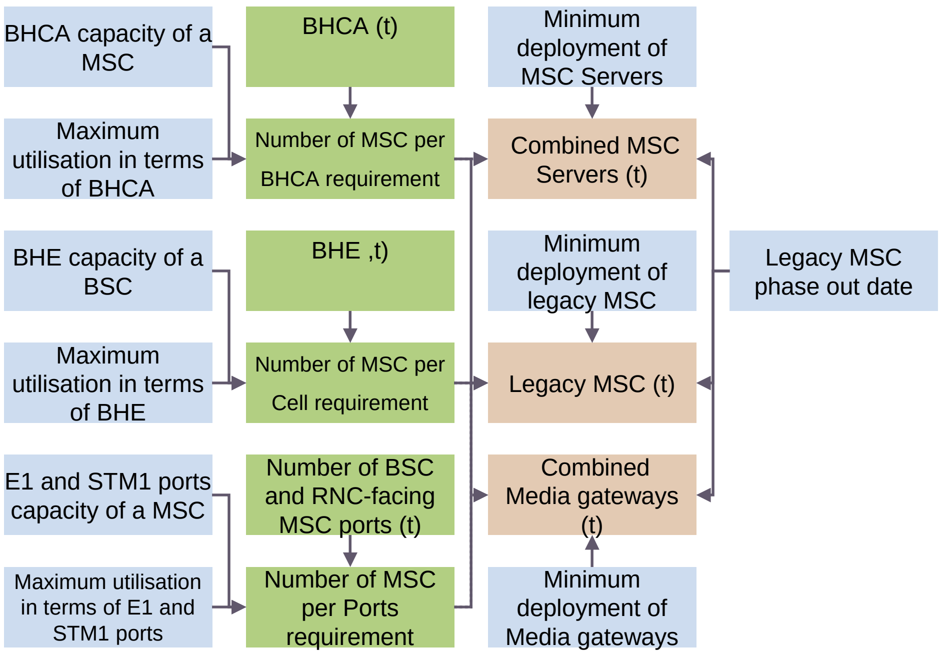
Calculation of RNC deployment and port dimensioning



- RNC units deployment is driven by three requirements:
  - maximum throughput in Mbit/s (assessed in the downlink direction), assuming a maximum utilisation
  - maximum number of E1 ports connected, assuming a maximum utilisation
  - minimum number of 13 RNCs deployed in the network for redundancy
- Each of those three requirements leads to a different number of RNC units:
  - the total number of RNCs is the highest of those three values
- RNC incoming ports (ports facing NodeBs) are directly derived from the number of backhaul E1 links, all technologies included
- RNC–MSC links and core-facing E1 or STM1 ports are dimensioned based on the average RNC downlink throughput:
  - taking into account a utilisation factor that reflects among other things the need for redundant ports and links

MSC unit deployment

Calculation of MSC deployment



- The number of 2G MSCs is driven by the largest of:
  - voice traffic load (BHE)
  - processing capacity (BHCA)
  - number of BSC and RNC facing E1 ports required
  - a minimum of two MSC for redundancy
- In the 3G layered architecture, MSC servers are driven by the processing capacity driver (BHCA) while MGWs are driven by the voice traffic load and the BSC/RNC port requirements:
  - a parameter specifies the date after which 2G/3G MSCs are phased out and replaced by MSC-S and MGWs
- Two parameters specify the maximum number of main switching sites and voicemail hosting sites
  - this is to model the point at which an operator starts doubling up MSCs in its switching sites

Reference table for linking the number of MSCs to key parameters

- The number of MSC locations takes into account a maximum number of MSC sites
- The number of inter-switch logical routes, based on the *fully-meshed* formula n(n-1)/2 where *n* is the number of MSCs, is further split between remote and co-located routes based on the average number of MSCs per location
- The number of POIs takes into account the proportion of MSCs that act as POIs:
  - the number of interconnect logical routes is based on the number of third parties connected in each POI and takes into account a maximum number of interconnection routes
- The number of VMS locations takes into account a maximum number of VMS sites:
  - the number of VMS logical routes is based on a full mesh between all MSCs and the VMS
- The proportions of various traffic types transiting on inter-switch logical routes are based on operator's submitted data

Core network reference table

increasing number of MSC (not shown here)

# MSC	3
# MSC locations	3
# MSC per location	1.0
# Inter-switch logical routes	3
# Inter-switch logical routes (remote)	3
# Inter-switch logical routes (coloc)	0
# POIs	3
# Interconnect logical routes	7.5
# VMS sites	2
# VMS logical routes	6
# VMS logical routes (remote)	4
% incoming traffic on inter-switch logical routes: INCLUDES inte	59%
% outgoing traffic on inter-switch logical routes: INCLUDES inte	13.2%
% on-net traffic on inter-switch logical routes: INCLUDES inter-M	42%
% international traffic on inter-switch logical routes: INCLUDES	36%

This MSC reference table is the main determinant of core network inter-switch dimensioning. Having calculated the number of MSC *according to MSC capacity*, we then use the reference table to find out: how many MSC locations, how many routes of different types, proportions of traffic between switches, etc. This table aims to condense the complex core network topology upgrade process into a logical but reflective network design algorithm

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Sheet: Network_design, Rows 1202-1233

MSC incoming and outgoing ports and transmission requirements

- MSC incoming ports (BSC- and RNC-facing) are directly derived from the BSC and RNC dimensioning calculations
- Interconnect ports are based on the number of logical routes (trunks) between operators and third parties and on the interconnect BHE load:
  - incoming and outgoing ports are calculated separately
  - calculations assume an interconnect link utilisation factor
- Inter-switch traffic is first calculated as a proportion of total traffic, then allocated to either distant or co-located links based on the ratio between the number of switches and number of switching sites
- Voicemail ports are based on the number of logical routes between all MSCs and the number of VMS sites. It is assumed that VMS are hosted on one or several of the main switching sites
- MSC ports are expressed in E1 equivalents while corresponding transmission links are expressed in either E1 or STM1 equivalents

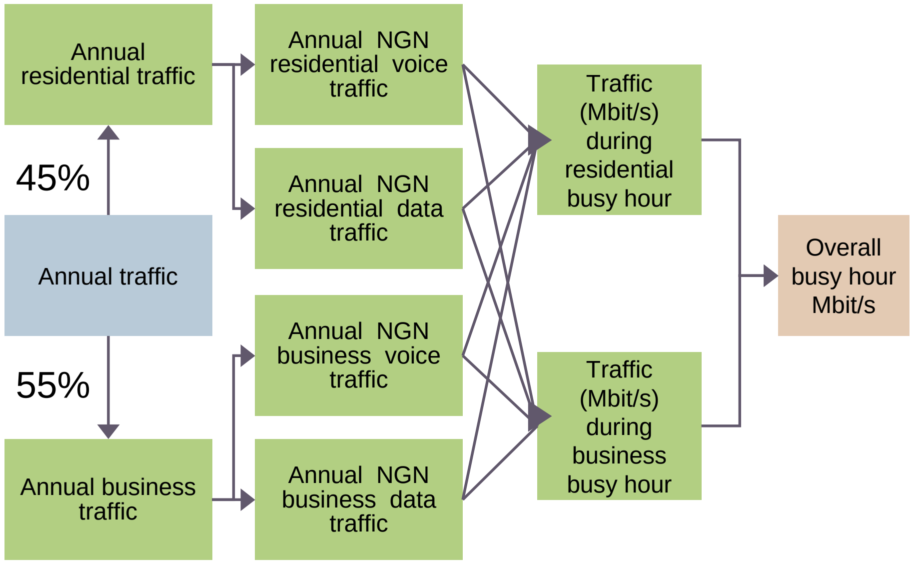
Sheet: Network_design, Rows 1235-1311

Mobile network design

Fixed network design

NGN busy-hour traffic calculation

Calculation of NGN-busy hour traffic

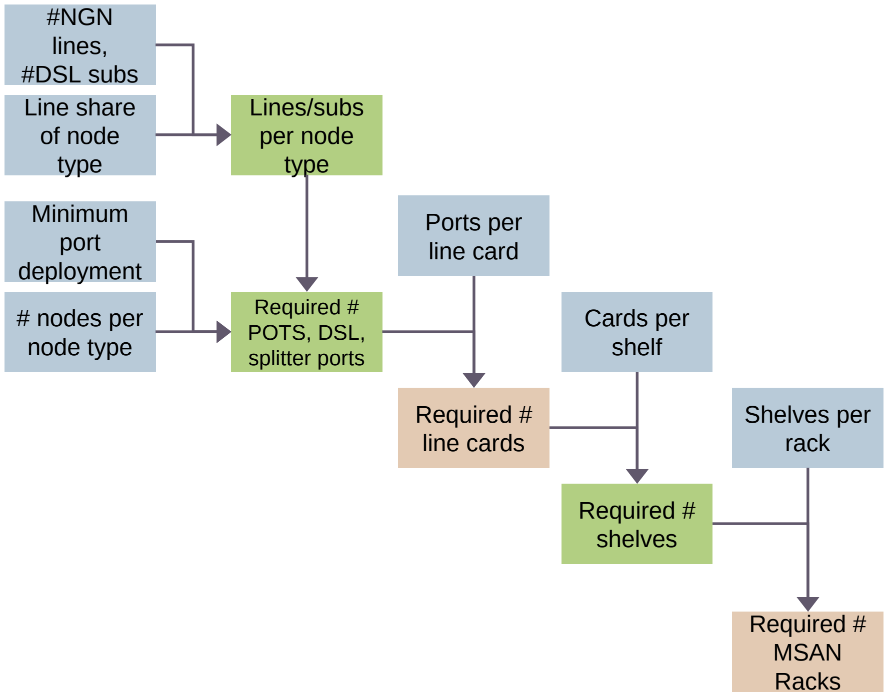


- The calculation of the NGN-busy hour requires separate treatment of residential traffic and business traffic because the hour-of-day and the day-of-week traffic profiles differ
- Therefore, the total annual traffic is first split into residential traffic and business traffic using an assumed traffic ratio
- Then, the voice and data annual traffic volumes are converted into busy hour traffic volumes using appropriate busy-hour parameters, contention ratios and conversion ratios
- The overall busy-hour traffic is then determined as the maximum of the residential and business busy hour

Sheet: Demand_subs_calc

Line card and MSAN deployment

Calculation of the required number of line cards and MSAN racks

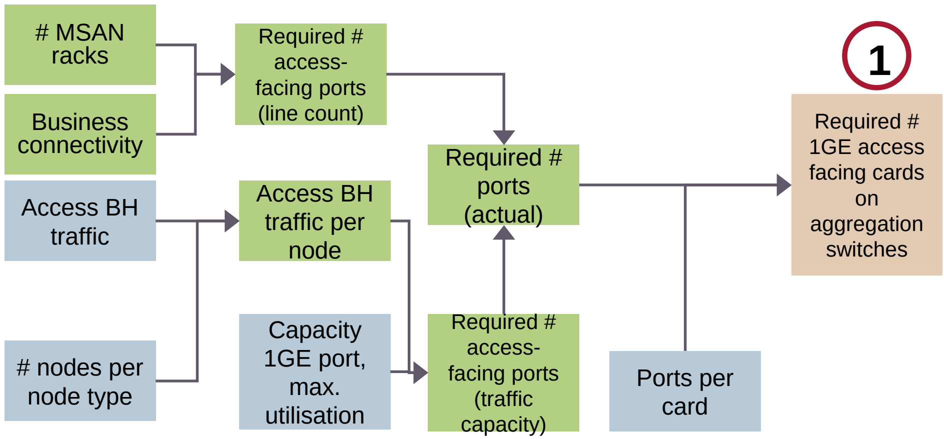


- The number of NGN lines and DSL subscribers drives the required number of POTS, DSL and splitter line ports, taking into account
  - the line share of each node type
  - minimum port deployment numbers
- Based on line card size, shelf space and rack space, the total required number of lines cards and MSAN racks are calculated

Sheet: Network_Design, Rows 19–61, 147-189, 329-371, 588-630

Access-facing aggregation switch port deployment

Calculation of the required number of access-facing switch ports

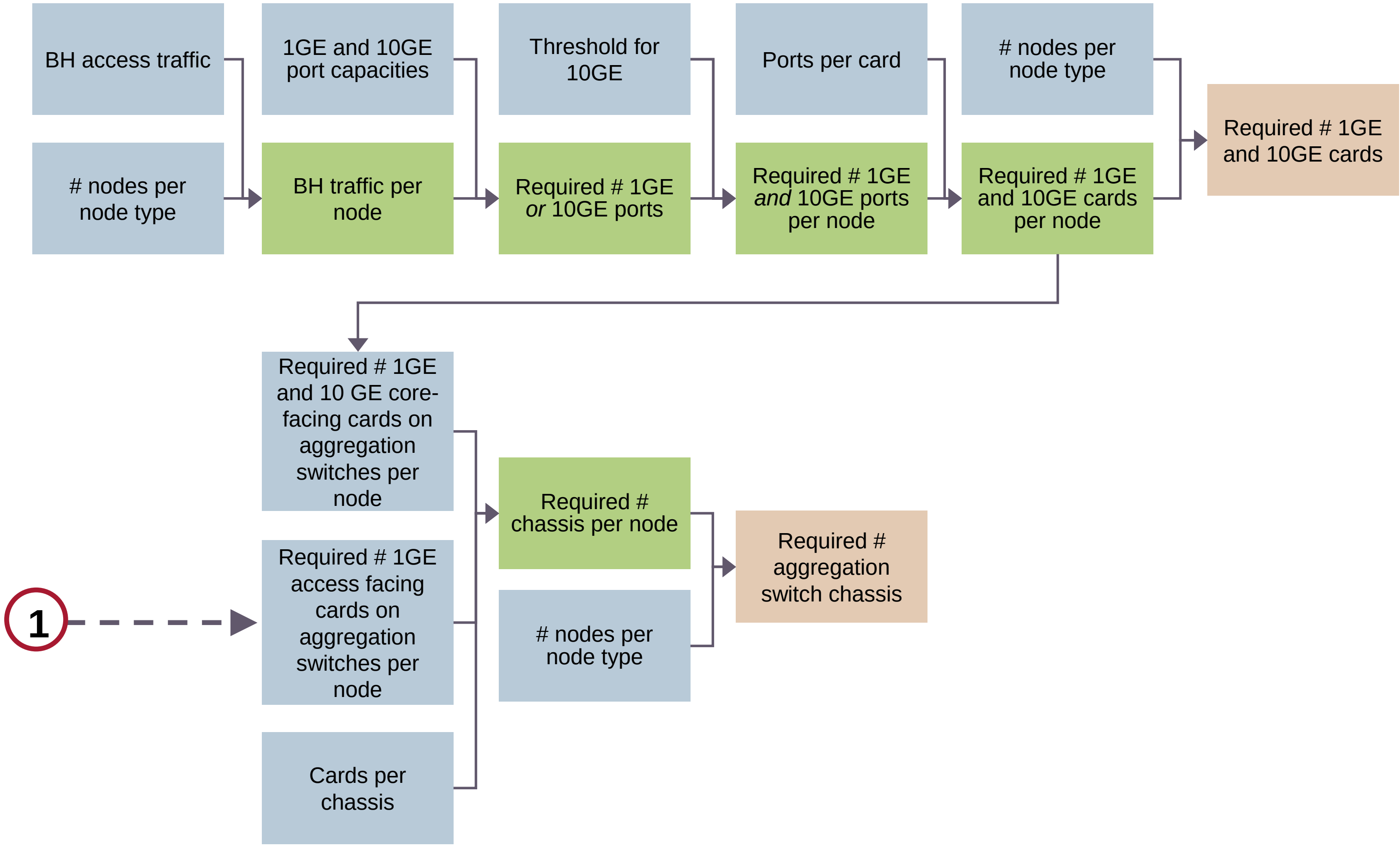


- The required number of 1GE access-facing ports (and cards) on the aggregation switches is initially determined by:
  - The number of MSAN racks deployed: each MSAN required requires 1GE port on the aggregation switch
  - Depending on node type, an additional 1GE port is deployed to support business connectivity
- In case total traffic on the access exceeds the capacity offered by the number of ports thus calculated, then the required number of ports is driven by total traffic (capacity-driven) instead of by the number of MSAN racks and business connectivity (count-driven)
- In case only 1 port is thus determined to be needed, then the algorithm rounds this down to zero, as in that case no aggregation switch is required at all

Sheet: Network_Design, Rows 67–79, 195-207, 375-389, 634-648

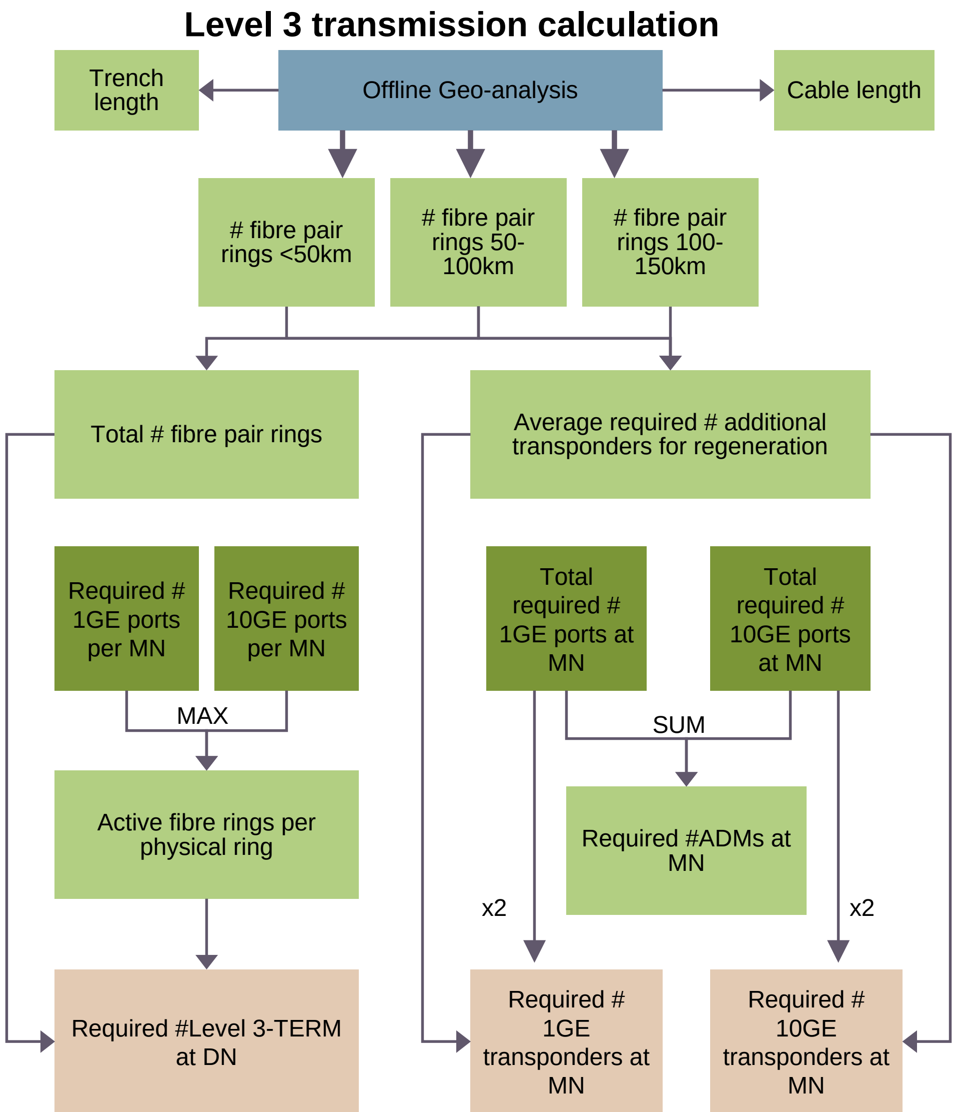
Core-facing aggregation switch port deployment and chassis count

Calculation of required number of core-facing ports and aggregation switch chassis



Sheet: Network_Design, Rows 81–122, 209-250, 391-432, 650-691

Level 3 transmission

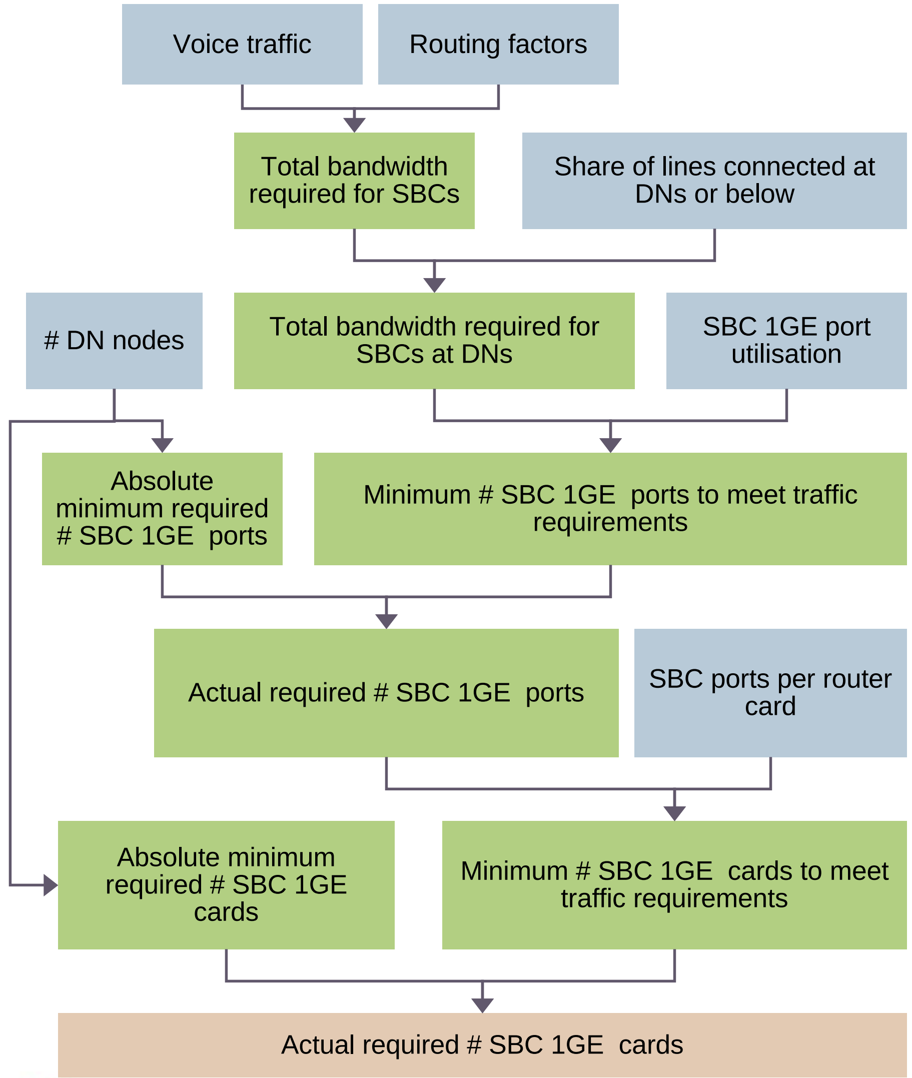


- Level-3 rings connect metro nodes to parent national, core or distribution nodes using geo-analysis
- Based on an 8-wavelength CWDM system, a maximum of 8 active nodes per ring are connected
- In the cases where the number of nodes exceeds 8, an additional fibre pair is installed such that every odd node connects to one fibre pair and every even node connects to the other fibre pair
- To determine the number of regeneration points required, we consider rings in categories of:
  - up to 50km
  - 50-100km
  - 100-150km

Sheet: Network_Design, Rows 264–317

SBC deployment

SBC calculation (example: at distribution nodes)

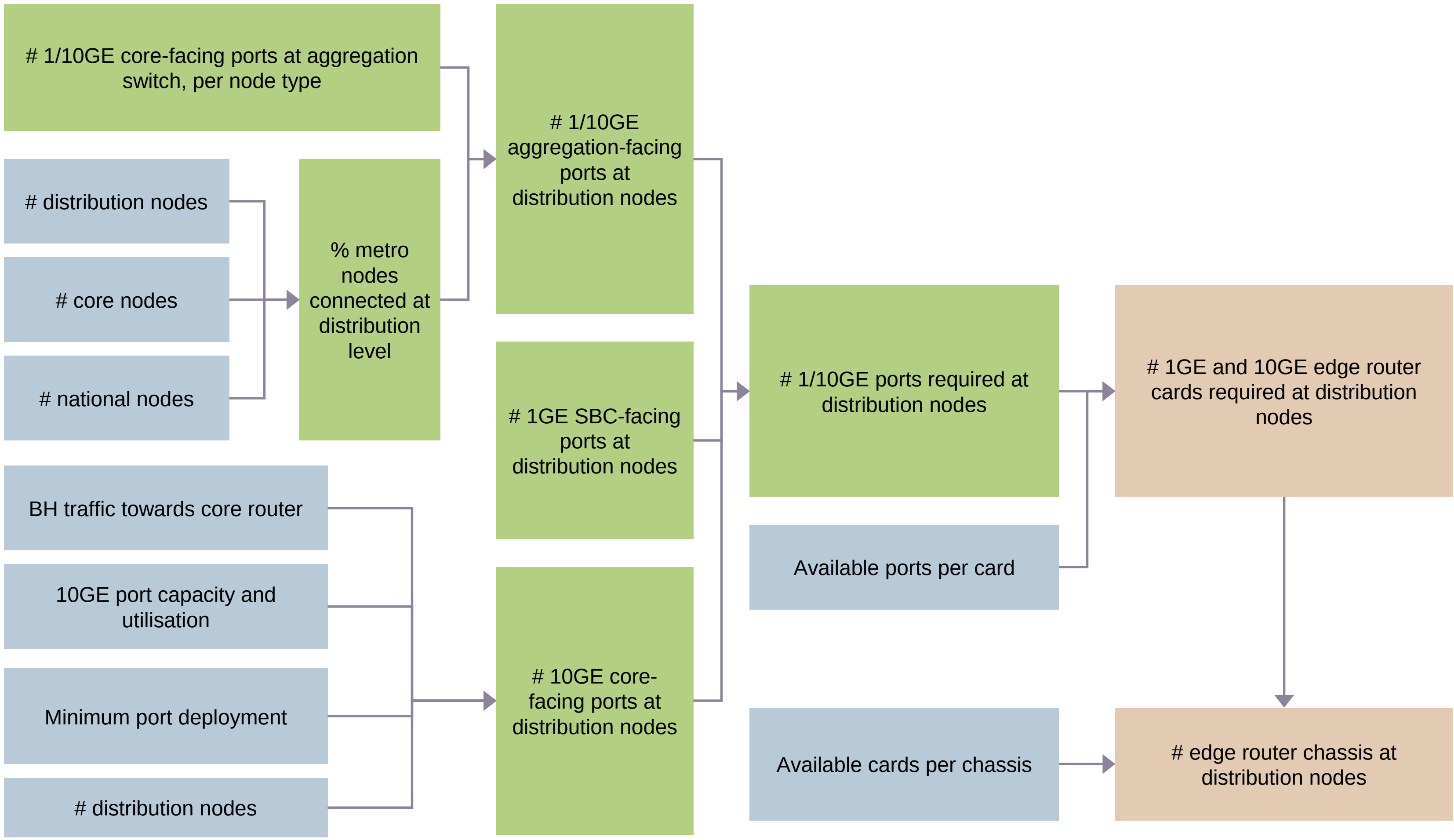


- SBCs are present at all distribution, core and national nodes (the figure on the left shows the distribution node SBCs as an example)
- The SBCs capacities are driven by SBC-routed voice traffic (on-net, outgoing and incoming voice), assuming
  - 1GE ports
  - 8 ports per card
  - a minimum deployment of 1 port/1 card per SBC location
- Additionally, the SBCs at national level also route the interconnect voice traffic (outgoing, incoming and transit voice)

Sheet: Network_Design, Rows 506–515, 763-792

Edge router deployment

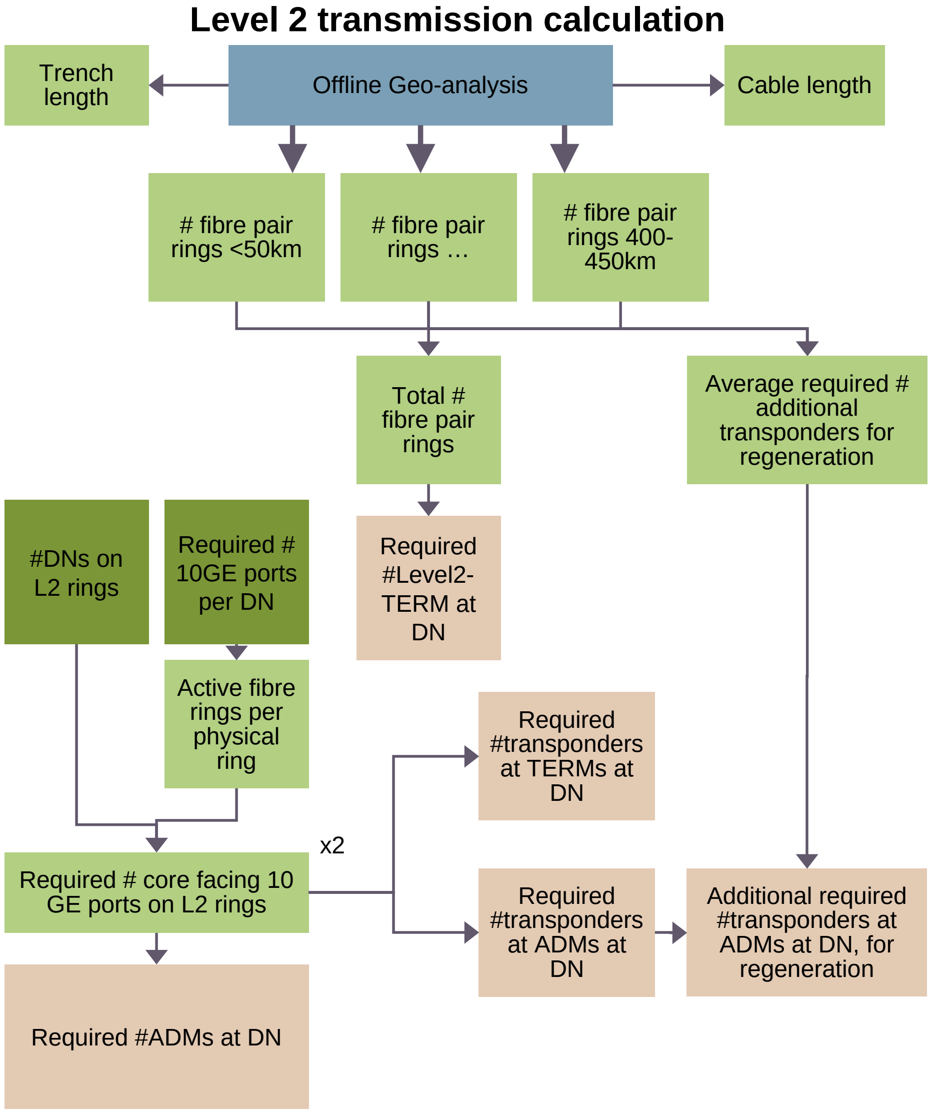
Calculation of the required number of edge router ports and chassis



Note: for the national nodes, additional ports facing the national switches are modelled

Sheet: Network_Design, Rows 447–504, 706-761

Level 2 transmission

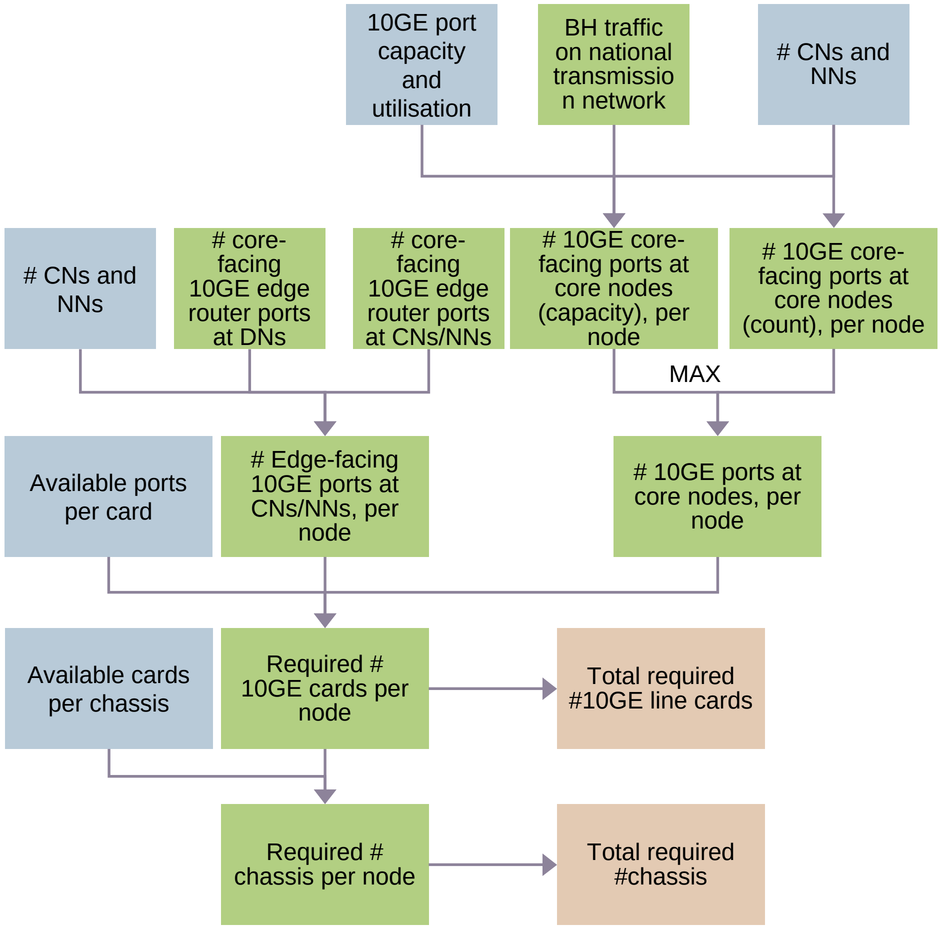


Sheet: Network_Design, Rows 517–573

- Level-2 rings connect distribution nodes to the core nodes
- Based on an 8-wavelength CWDM system, a maximum of 8 active nodes per ring are connected
- In the cases where the number of nodes exceeds 8, an additional fibre pair is installed such that every odd node connects to one fibre pair and every even node connects to the other fibre pair
- To determine the number of regeneration points required, we consider rings in 9 categories ranging from:
  - up to 50km as the smallest ring, to
  - 400-450km as the largest ring

Core router deployment

Calculation of the required number of core router ports and chassis

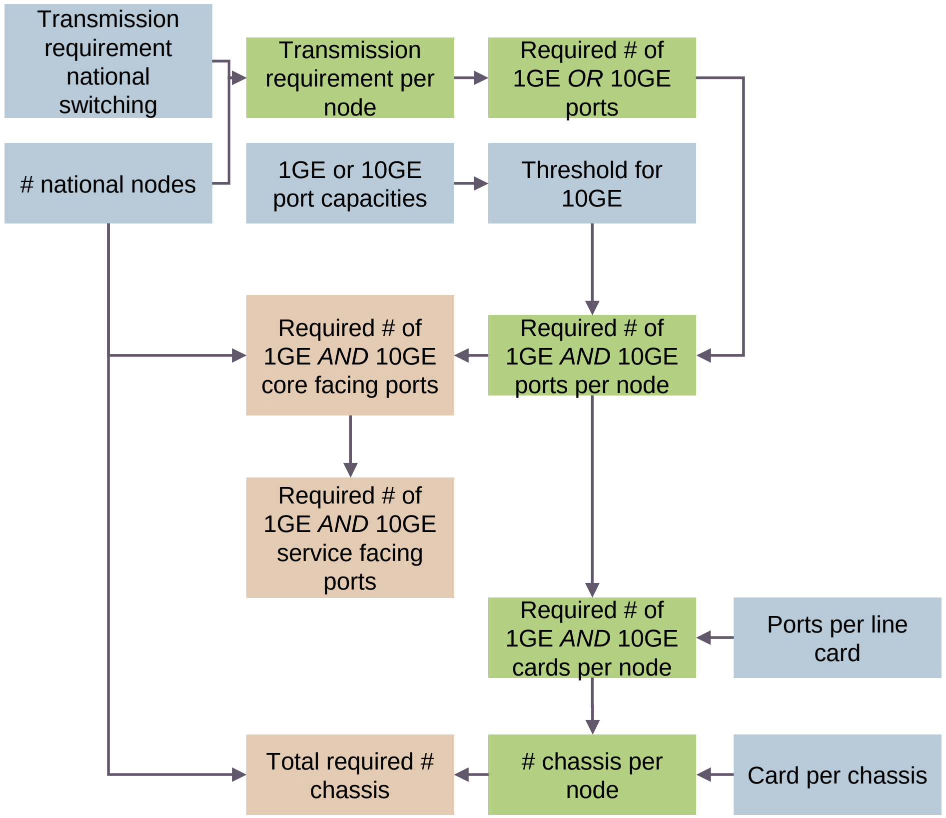


- Core routers are deployed at every core and national node
- Their deployment is driven by
  - the number of core-facing edge router 1/10GE ports at the distribution, core and national nodes
  - the number of ports to other core routers, determined by core network traffic, 10GE port capacity, 40% port utilisation, 1 port per card, and 15 cards per chassis

Sheet: Network_Design, Rows 794–822

National switching deployment

Calculation of the required number of national switching ports and chassis

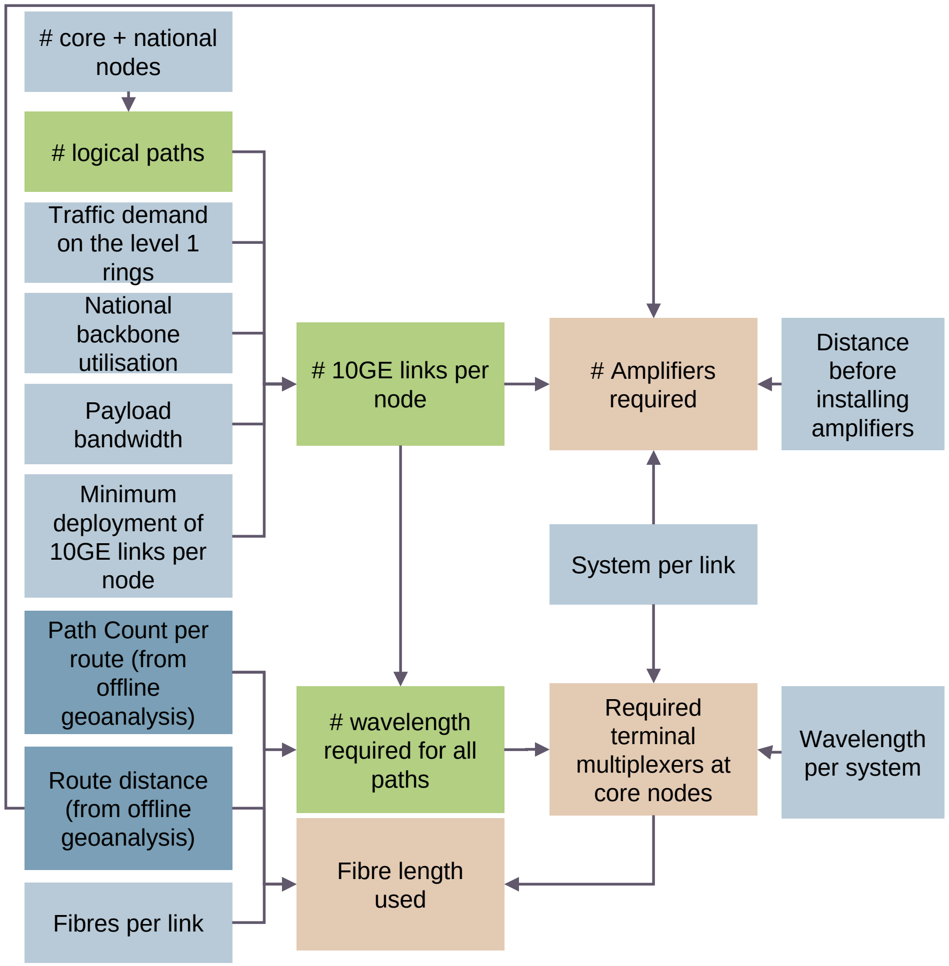


- For Internet peering and to connect TV/VoD platforms, an additional switch per national location is deployed
- National switching deployment is driven by
  - xDSL traffic
  - TV traffic
  - VoD traffic
- If more than 2x1Gbit/s Ethernet ports are required, an upgrade to 10Gbit/s Ethernet ports is triggered
- Capacity utilisation parameters are set to 40% to allow for redundancy in ports/cards/transmission
- The following technical parameters have been assumed:
  - 48 ports per 1GE card
  - 12 ports per 10GE card
  - 6 switch slots per chassis

Sheet: Network_Design, Rows 841–906

Level 1 transmission

Level 1 transmission calculation



- We model *protection* of the transmission capacity using a national backbone utilisation factor less than 50% - i.e. provision of diverse transmission capacity
- For DWDM systems, it is assumed that an amplifier needs to be installed every 80km to maintain signal strength
- The number of logical routes is based on the *fully-meshed* formula n(n-1)/2 where *n* is the number of core and national nodes.

Sheet: Network_Design, Rows 1061–1115

Contact points

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