פרונטיר
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Estimating the cost of Wholesale Access Services on HOT's network

MODEL DOCUMENTATION

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Content:

Estimating The cost of Wholesale Access Services on HOT’s network

List of Figures:

List of Tables:

1 Introduction and summary

We have been retained by the Ministry of Communications (MOC) to develop a model for calculating the normative costs of wholesale access, broadband, and broadcasting transport of an efficient operator with the network technology and service demand of HOT's hybrid fiber coaxial network. We refer to this as the *cable* network, i.e. contrary to a *fixed* network with the technology and service demand similar to those on Bezeq's network. These costs form part of the information considered by the MOC in its current process for determining regulated prices for wholesale services, following the recommendations of the Gronau and Hayek Committees.

This report focuses explicitly on the costs of the following wholesale services:

- wholesale access;
- bitstream transport; and
- wholesale broadcasting transport (Multicast service).[1]

The model documented in this report also reflects the MOC decisions in relation to fixed termination rates and Bitstream and infrastructure service costs on the fixed network for determining some of the assumptions made in this model where relevant.[2]

1.1 Basis of the model development

The model is based on a bottom-up LRAIC (long run average incremental cost – also known as TSLRIC) methodology. A LRAIC approach was chosen to adequately cover the incremental costs incurred for providing individual services over the network but to also ensure the recovery of fixed and common costs an efficient operator incurs. This approach has been widely used in regulatory proceedings for calculating the cost of regulated wholesale services, such as Bitstream Access (BSA), local loop unbundling (LLU)and was also used to model Bezeq's fixed network[3]. A number of countries have or are in the process of

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1 For the provision of audio visual broadcasting services by access seekers; provision through IP data stream and EPG reprogramming.

2 See final decision concerning wholesale services rates in Bezeq's network, dated 17.11.14. available at http://www.moc.gov.il/sip_storage/FILES/0/3960.pdf

3 See "Estimating the cost of a Wholesale Access Service on Bezeq's network – Model Documentation", August 2014, http://www.moc.gov.il/sip_storage/FILES/4/3794.pdf, hence forth "the fixed model documentation".

using an alternative measure, known as a pure-LRIC[4] approach for setting the termination rate for fixed (and mobile) voice services, but not for other services. A LRAIC approach differs from pure-LRIC in that it includes common costs when estimating wholesale service costs.

The model is forward looking in that it considers a hybrid fiber coaxial access network, NGN technology in the core and DOCSIS 3.0 technology. The model estimates costs for the period 2015 to 2018. The approach also takes into account the general structure of the network that HOT currently has in place but taking into account some of the upgrades currently undertaken. This is detailed in chapter 3.

1.2 Service costs estimates

This document discusses the process for estimating the cost of wholesale access and bitstream and broadcasting transport and shows the costs calculated in the model. The costs of the services depend on a number of assumptions that were determined after consultation with MOC. These relate to capital and operating cost data used in the model and also to service demand forecasts.

In summary, based on the calculations described in this document, the model calculates the following cost estimates for 2015:

Table 1. Summary of estimated costs (2015)

	Unit	Cost
Wholesale access	NIS/access/month	37.14
Bitstream transport	NIS/Mbps/month	21.37
Broadcasting transport	NIS/Mbps/month	9,996

The remainder of this document provides a summary of the approach used to estimate the cost of these services and is structured as follows:

- Section 2 describes the demand considered in the model;
- Section 3 provides an overview of the structure of the cable network;

4 A pure LRIC approach measures the marginal costs of a service. i.e. the additional cost an operator incurs from providing a service compared to the total cost it incurs when not providing that service.

- Section 4 describes how the model determines the infrastructure and equipment in the core and access network;
- Section 5 describes the calculation of the capital and operating costs of the access and core network infrastructure and equipment; and
- Section 6 presents the results of the model.

The annex to this document provides relevant references to the Danish model considered as benchmark for some of the inputs to this model.[5]

5 Other reference models that where used to determine some assumptions taken from the fixed model are referenced in the annex of the fixed model documentation.

2 Forecasting service demand

The cable network is used to provide voice, broadband, broadcasting and video on demand (VoD) services. The capacity required for all of these services needs to be reflected in the model because communication networks typically have positive returns to scale and scope and not covering all services increases the risk of overestimating the costs of individual services.

For each service, the model estimates the amount of capacity or volume of traffic generated per subscriber or total capacity required for a service. This estimation is typically based on the following three steps:

- the model forecasts the total population, households and service penetration which forms the basis of the market the cable network is providing its services to;
- the model then forecasts the market share of the cable network;
- the model then forecasts voice, broadband, broadcasting and video on demand (VoD) usage (traffic or capacity) either on a per subscriber basis or total usage; and
- where service demand is estimated on a per subscriber basis, the final step involves multiplying the per subscriber traffic/capacity with the number of subscribers according the cable operators market share forecast.

The following sections outline the forecasts of subscribers and traffic/capacity.

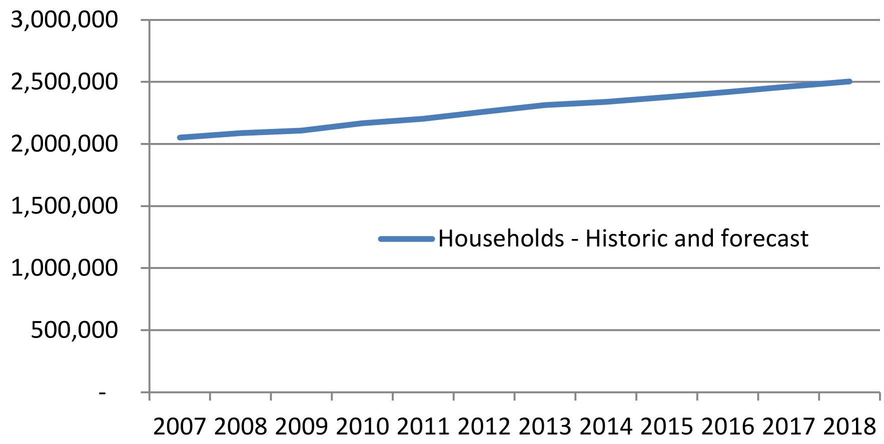
2.1 Forecasting service subscribers

The following sections set out the forecast of service subscribers. Services are forecasted individually but also the total number of subscribers (i.e. taking into account the overlap of service subscribers as a result of customers subscribing to more than one or two services).

2.1.1 Voice and broadband subscribers

The forecast of voice and broadband subscribers is based on the long term trend of these subscribers in relation to the number of households in Israel. For that the model estimates the growth of the population and applies an estimate of the size of households to forecast the total number of households. Figure 1 outlines the historic development and forecast of the number of households in Israel.

Figure 1. Households in Israel -

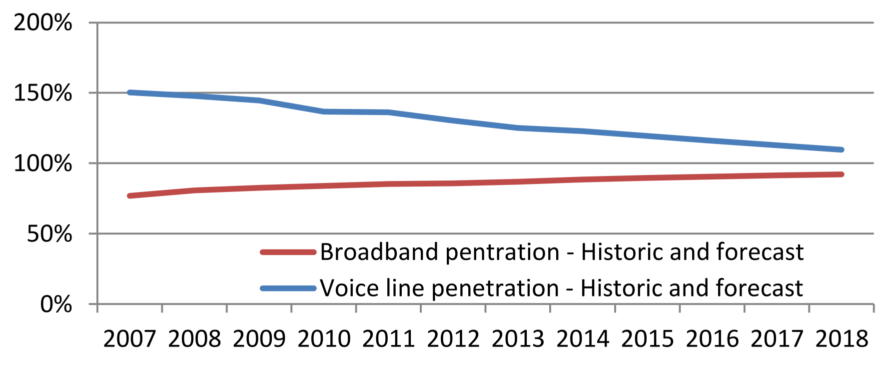


Source: Projection based on CBS data

The forecast is based on a linear projection of the households and population. The population is based on CBS data up to 2014. The number of households is based on CBS data up to 2013 (the last year for which household data is available) and the forecast is based on the average size of households in 2007 to 2013 (at 3.55 persons per household). This is applied to the 2014 population and the 2015 – 2018 population forecast to derive the forecast for the number of households.

The total number of subscribers of voice and broadband services is then measured as the level of penetration relative to the number of households. The forecast is based on applying a linear trend to the historic development of voice and broadband subscriptions.

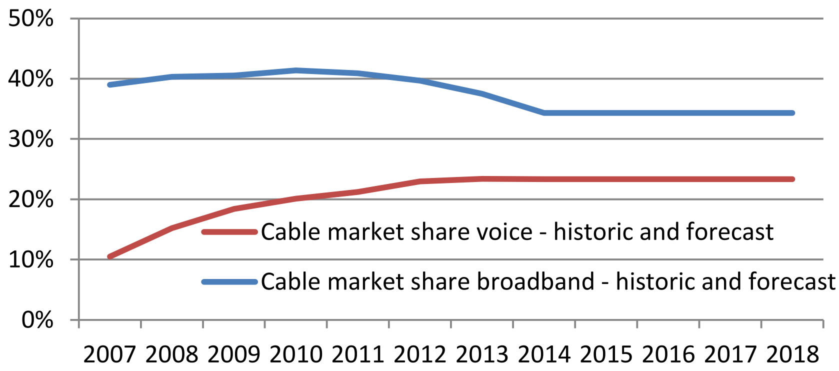
Figure 2. Broadband and voice penetration



Source: Projections based on TeleGeography and CBS data

The final step in the determination of the cable operator subscriber volumes is the projection of market shares. Our estimates are based on the development of the market shares for voice and broadband services of HOT and Bezeq. Figure 3 shows the historic market shares and projections used for modelling the cable network. The forecast does not take into account the potential roll-out of a third network operator in Israel. This is because the timing and extent of a roll-out are still too uncertain to reliably determine a corresponding market share. However, we suggest that the MOC revisit the model in two years in light of significant changes in market shares.[6]

Figure 3. Market shares of cable voice and broadband subscribers



Source: Projections based on TeleGeography data

Market shares for fixed broadband services have been stable since 2007 until 2012 at around 40%. However, the last two years have seen a notable reduction in the cable market share, significant enough to suggest that the market share may permanently drop below 40%. Instead, we assume that market shares of cable will remain at a lower level of approximately 34% of the market. Market shares of fixed voice services have increased at a lower rate year on year eventually remaining flat for the last two years. This is the basis for assuming that the voice service market share for cable will remain constant at approximately […]%. .

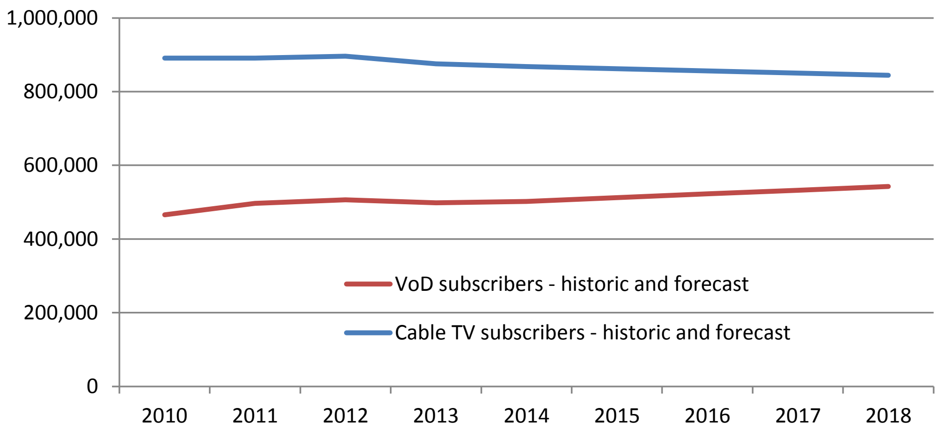
2.1.2 TV and VoD subscribers

The number of cable TV subscribers is an input for determining the total number of subscribers on the cable network and for determining the forecast of VoD subscribers. The number of VoD subscribers, contrary to the number of

6 The MOC intends to publish a consultation concerning a suggested mechanism for revisiting the demand projections and their update (if required).

cable TV subscribers, also drives the total capacity required for carrying on-demand traffic. The forecast for cable TV subscribers is based on the linear extrapolation of the historic cable TV penetration. The number of VoD subscriber is based on a linear extrapolation of the historic ratio between cable TV and VoD subscriber. This is reasonable given the past development of TV and VoD subscribers on the cable network where closely linked. Figure 4 shows the total number of Cable TV and VoD subscribers.

Figure 4. Cable TV and VoD subscribers

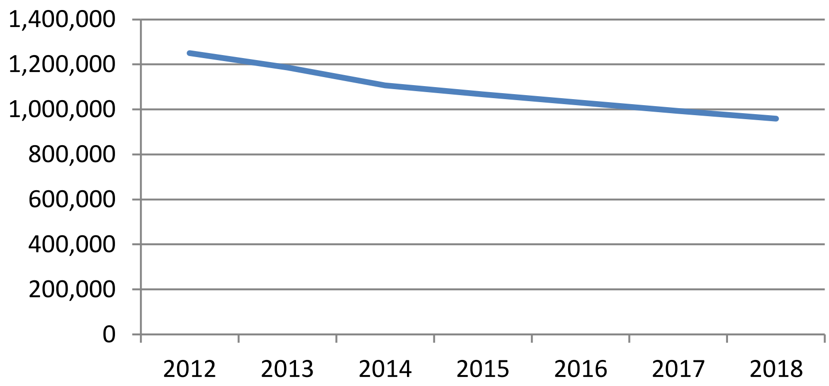


Source: Projections based on HOT data

2.1.3 Total cable network subscribers

The cable network offers provision of single, double, and triple play services. In order to determine the total number of unique subscribers (one unique subscriber can subscribe to one or more services) information from HOT for 2012 and 2014 on the distribution of single, double and triple play services was used. Based on that information, unique subscribers represented 53% of the total number of services in 2012 and approximately 50% in 2014, i.e. approximately two services per subscriber. Based on this, the model forecasts a declining ratio (i.e. an increase in the number of services per subscriber) down to 43% in 2018.

Figure 5. Unique subscribers on cable network



Source: Projections based on HOT data

2.2 Forecasting service usage

The dimensioning of the network is not just based on the number of subscribers but primarily the result of the traffic those customers generate and the capacities required for provisioning this. The following sections set out the usage in form of traffic or capacity requirements on a per subscriber or total capacity basis.

2.2.1 Voice traffic

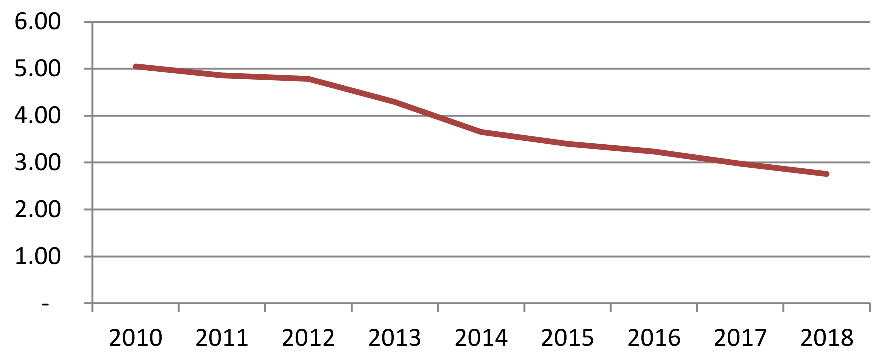
The voice services covered in the model include all types of calls, disaggregated into the following categories:

- On-net fixed calls;
- Calls to and from other fixed and mobile numbers;
- International calls (incoming and outgoing); and
- Other calls.

Historically, demand for calls on HOT's network has developed differently for each type of call. This is both because competition for these services has developed differently (especially for international calls) and because mobile services have grown in importance.

Changes in traffic volumes can occur for two reasons. Firstly, total traffic changes because the number of customers changes. And secondly, changes in traffic occur due to changes in customer behavior. To effectively isolate these two effects, we forecast the traffic for different types of calls on a per subscriber basis. The total voice traffic in any given year is then given by the forecast traffic per subscriber multiplied with the forecasted number of voice subscribers. Figure 6 shows the total voice traffic for the modeled period.

Figure 6. Total annual voice traffic (bn minutes)



Source: Projections based on HOT traffic

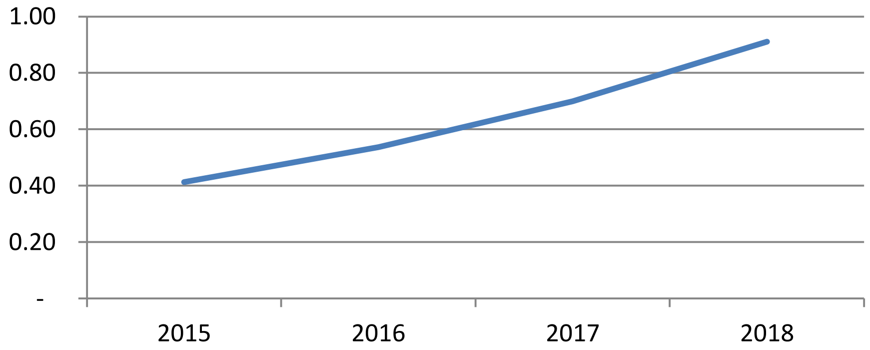
2.2.2 Broadband capacity

Broadband services in Israel consist of xDSL based services over Bezeq's network and Cable based services from HOT. The network dimensioning of the cable network is therefore based on the number and capacity of the cable broadband services it provides. These services are offered with different upload and download speeds and the speed of a service will typically impact the capacity required for that service on the network.

The forecast of broadband traffic is based on the effective interconnection capacity between network operators and ISPs in Israel. Due to the structure of the market with network operators and ISPs as different companies, this data provides a longer, more consistent trend of the effective capacity required on the network. Additionally, it captures the actual usage of network capacity, rather than extrapolating based on nominal broadband speeds. The data in the model is the same that was used in the fixed bottom-up model[7] complemented with the most recent measurements from January 2015 which supports the general trend previously considered. This is further explained in Levaot – Gronau Recommendations concerning wholesale services pricing over Hot's network.

7 This is based on an average of all broadband subscribers in Israel as measured at the point of interconnection between ISPs and network operators.

Figure 7. Core network capacity per broadband subscribers (Mbps)



Source: Projections based on level and growth of ISP interconnect capacity and international benchmark of broadband capacity growth

In addition to the core network capacity, the model considers the provisioned capacity in the access part of the network. This is necessary to dimension the broadband specific equipment at the headend (CMTS) and the number of channels required for broadband on the access network. This is done by linking the current amount of access specific capacity and the capacity on the core network. The most recent available information for 2014 suggests a configuration of customer premise equipment of 8 channels for the downstream and 4 for the upstream. This is based on the configuration of mass market customer premise equipment (CPE) which was updated to 8 and 4 channels in 2013. In addition, HOT stated for 2014 its plan to upgrade the cable network by further segmentation the service groups (Hot's Upgrade Project).The Upgraded network dimensioning provides one downstream segment for broadband services to 1000 customers while an upstream segment is provided to 500 customers. The MOC is aware that extensive areas still don't match those principles, i.e. the actual dimensioning in most areas on average is one upstream and downstream segment to 2000 customers but, in the context of developing a notional network model, considers it appropriate to model the entire network based on the best practice principle, which corresponds to Hot's planned dimensioning.[8] 8 channels at 50 Mbps per channel imply an average downstream capacity of 0.4 Mbps per subscriber in the access network; 26% higher than the core capacity in 2014. This factor (1.25) is then used to estimate access capacities on the basis of the core capacity forecast set out in Figure 7 above.

8 We note that considering this upgraded deployment allows to disregard temporary capacity limitations in the current network.

Finally, for estimating the number of channels in the access network it is also necessary to consider upstream traffic separate from downstream traffic. Current offers with 5 Mbps maximum upstream traffic suggest that the network provides a maximum capacity of 72 Mbps of upstream traffic. This is based on the fact that the current upstream network is modulated at 16 QAM assuming channel bandwidths of 6.4 MHz. At 500 customers covered per service group, this implies an average provisioned capacity of 0.14 Mbps or 36% of downstream capacity in the access network.

The model assumes that these ratios remain constant and forecasts the amount of access downstream and upstream capacities by applying ratios of 1.25 and 1.25 x 0.36 to the core downstream capacity forecast set out in Figure 7 above respectively.

2.2.3 Broadcasting capacity

The capacity required for TV services depends on the types and number of channels transmitted by the cable operator. It is independent of the number of subscribers on the network but requires the same capacity on every access segment of the network (the group of households connected on a final segment of coaxial cable).

The model distinguishes 4 types of TV channels, SD, HD, 3D and interactive.[9] The number of channels is based on forecasting the historic number of channels on HOT's network for each type separately:

- SD channels are expected to remain at 163; the same as currently in 2014 and similar to the average between 2012 -2014.
- HD channels are expected to remain at 22 based on the same principle as SD channels.
- One 3D channel was available in 2010 but has since been discontinued and the model assumes that no such channels are broadcasted.
- Interactive channels have decreased from initially 32 in 2010 to 18 in 2013 and 2014. The model therefore is based on a forecast of 18 channels.

Digital channels are assumed to require the following bandwidths based on information provided by HOT:

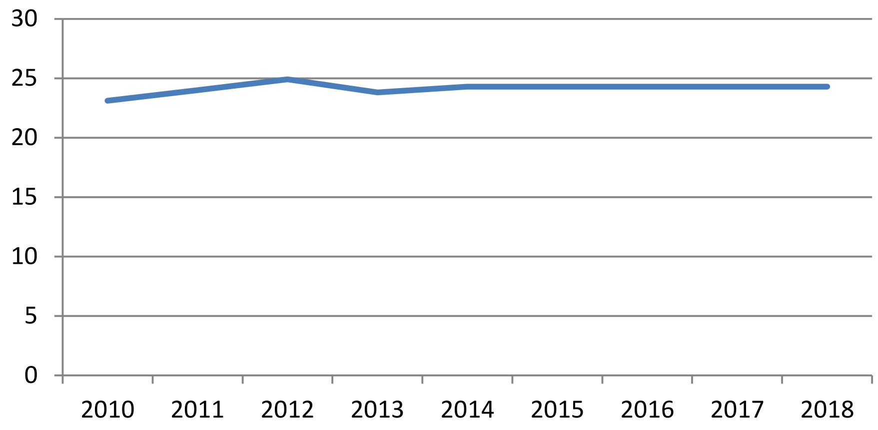
- SD – 3.4 Mbps

[9] The current network still broadcast analogue channels. However, this service and corresponding requirements are not included in the model. This is because the provision of analogue channels will terminate in 2015.

- HD – 6.8 Mbps
- 3D – 6.8 Mbps
- Interactive – 6 Mbps

The relevant information required for the dimensioning of the network is the number of channels occupied by the digital TV service. This is because the primary network element shared between the broadcasting and other services is the access network and especially the fiber network between headends and optical nodes. The usage of that part of the network is typically expressed in the number of radio frequency (RF) channels, i.e. channels of 8 MHz bandwidth (EuroDOCSIS) onto which all data and services are encoded for the transmission of the hybrid fiber coaxial access network. For converting the capacity per digital TV channels, the maximum capacity per 8MHz channel is considered at 35 Mbps after taking account of overheads (50 Mbps excluding 30% for overheads). The corresponding number of RF channels is shown in Figure 8 below.

Figure 8. Number of RF channels required for digital TV channels

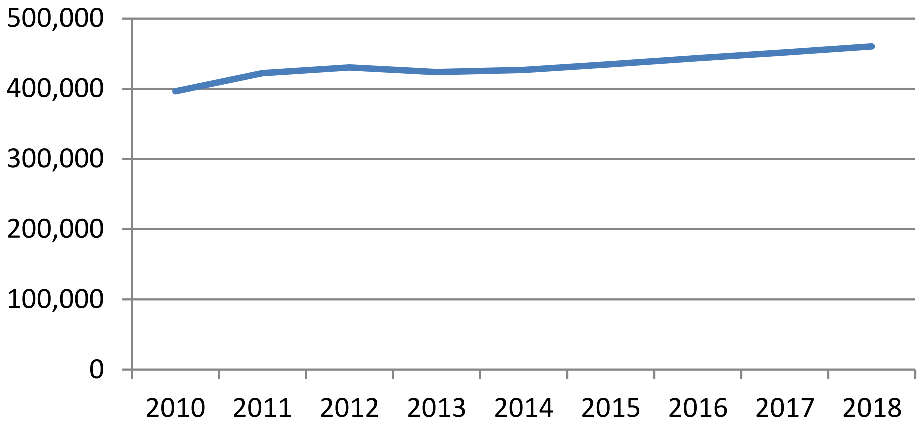


Source: Projections based on HOT data

2.2.4 VoD capacity

The capacity required for VoD traffic is based on the maximum number of concurrent VoD users and the average capacity per VoD user. The model assumes that the capacity per user is based on the SD channel capacity, i.e. 3.4 Mbps. The number of concurrent subscribers, i.e. the maximum share of VoD subscribers simultaneously accessing the service, is derived from HOT's current provision of 4 RF channels dedicated to VoD. This is equivalent to busy hour usage by […]% of the VoD subscribers. The corresponding total capacity is shown in Figure 9.

Figure 9. Peak capacity required for VoD content (Mbps)



Source: Projections based on HOT data

2.2.5 Multicast traffic

Consistent with the fixed network model, the cable model includes a wholesale broadcasting service for the provision of TV channels by access seekers. This is in accordance with a policy decision by the MOC which is set out by the Ministry under separate cover.[10]. The model therefore also estimates the cost of wholesale multicast traffic on the assumption (consistent with those considered in the fixed network model) that this consists of 4 standard definition TV channels each of which has a capacity of 2.6 Mbps[11]. As such, the model assumptions and corresponding costs of the service may be revised in response to any significant changes in the technical specification or increase in demand of the service, in terms of number of TV channels.[12]

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10 See BSA & Telephony Service File, incorporated into Hot's License, available at http://www.moc.gov.il/sip_storage/FILES/3/3963.pdf .

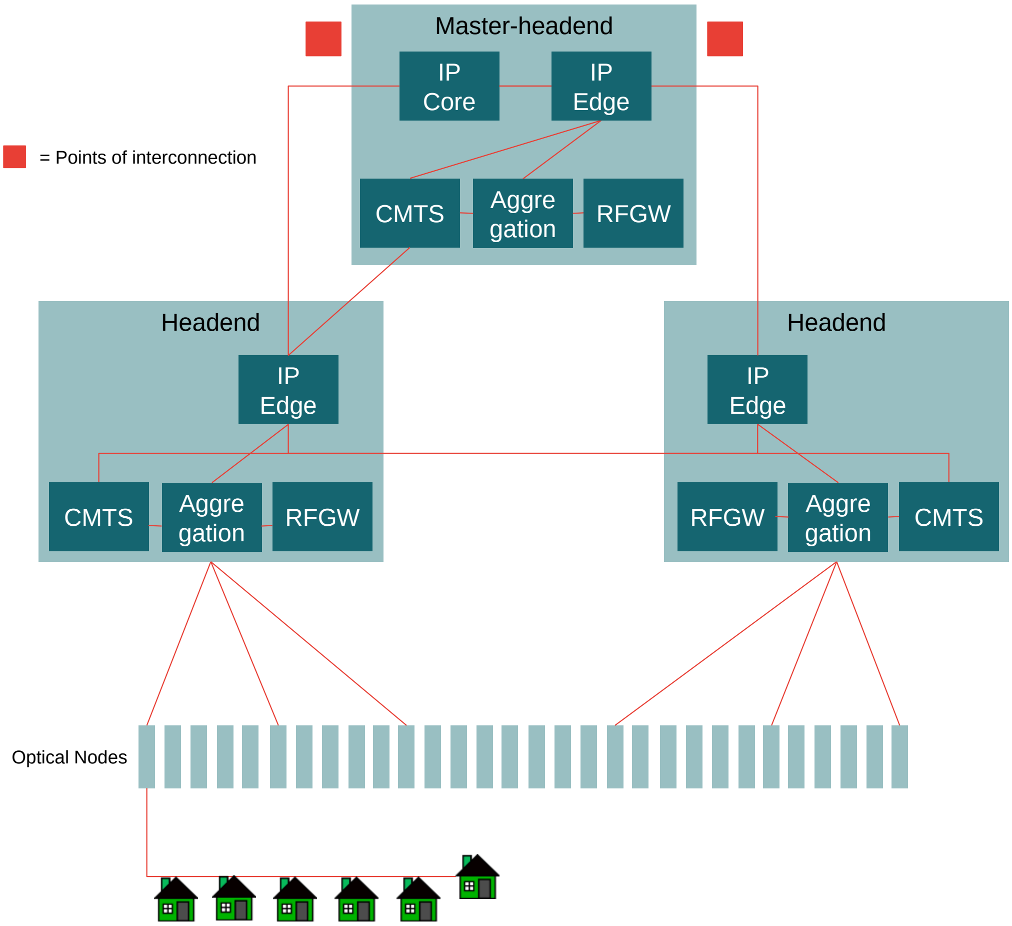
11 This is different from HOT's own SD channels (3.4 Mbps) because the transmission is carried out over the IP stream parallel to broadband traffic (not HOT's system for delivering digital TV channels). We therefore consider it more appropriate to apply the same technical assumptions for delivering the service used in the fixed network model.

12 Contrary to the assumptions made in the fixed network model (i.e. delivery of the multicast signal to 1000 MSANs) the HFC model assumes delivery of the signal to all optical nodes. This is because traffic on the HFC network is less costly and with costs similar to those in the fixed network model, delivering to all households would be commercially viable for access seekers.

3 Cable network structure

The model derives equipment and infrastructure requirements of a modern cable network operator using a hybrid coaxial fiber access network and DOCSIS 3.0 standard for the provision of broadband, voice and audiovisual services. The structure of the current cable network in Israel is used as a template for that network. In particular, we have taken the number of network nodes largely as given.[13] The broad structure of the network is set out in Figure 10 below.

Figure 10. HFC network structure



13 This mostly resembles a "scorched node" approach. The network topology is defined as the established network as "anchor asset". That is, it will not be feasible in the medium term to reduce the number of sites. The equipment located at each node is optimized to minimize the cost of the network.

Based on this overall structure, the model distinguishes between the access and the core part of the network. The access part is based on the current number of optical nodes (ON) and connected cables with the downlink to customer premises based on coaxial cables and the uplink to headends based on fiber optic cables. The infrastructure and equipment in this part of the network is passive.

Active equipment is located in headends and considered as part of the core network. Again, the current number of headends forms the basis of the network modelling with 18 headend sites and 3 master-headends (a subset of the 18 headend sites). Headends are considered to be placed in areas where the coverage of the aggregate customer base requires along with the CMTSs, a larger amount of active equipment including parts of the core IP network. Master-headends are considered to contain all of the above and additional core IP routers.

Radio frequency gateway (RFGW) equipment is used in headend locations to achieve a greater downstream port density to aid in the efficient coverage of the areas in Israel. In other words, the use of an RFGW enables the use of specific CMTS equipment with greater port density.

In addition to the number of nodes considered for the network, the linkage between nodes impacts the dimensioning and costs of the network equipment. The corresponding assumptions which are broadly based on the current cable network and consistent with standard engineering rules are set out in below.

Table 2. Equipment links

Equipment/Location	Links
Customer premise	The customer premise is passed by a single coaxial cable connected to an optical node – this is considered to be an access segment. (The model further distinguishes downstream and upstream segments for the dimensioning of headend equipment – these segments aggregate customers from several access segments. The details of this aggregation are set out in section 3)
Optical nodes	Each linked by optical fiber to one headend
Headend - RFGW	An RFGW is required in headend locations and links the broadband, voice, wholesale TV downstream traffic to the optical nodes receiving the traffic from the CMTS through an aggregator.
Headend - Aggregator	Located between CMTS and RFGW to ensure an efficient use of port RFGW port capacities
Headend - CMTS	Each linked to two edge routers
Headend - IP edge	Edge routers are linked to two IP core routers
Master-headend - IP core	Core routers are meshed

Each link is dimensioned to carry all the traffic between the equipment. This configuration, which corresponds to Hot's submissions concerning the one used in HOT's network, is efficient in the sense that the individual layers are needed to concentrate traffic and the equipment employed at each layer is not excessive. Further, the network provides both diverse routing and capacity resilience - both features of an efficient and reliable network.

4 Network dimensioning

This section describes the approach to dimensioning the cable network. For conceptual reasons, this is done separately for the access and core network. For the purpose of this description, we consider the access network to consist of the coaxial part of the network up to the optical node. The core network consists of the optical nodes and fibers to the headends and equipment and infrastructure in and between headends. Prior to setting out the dimensioning of the network we describe the approach for determining the capacity required for the provision of the services on the network. This forms the input to the dimensioning of the network and the allocation of costs to services.

4.1 Determining service capacity requirements

This section describes how the model determines the network capacity requirements from service demand inputs.

To dimension different types of equipment and allocate costs to services, we established for each network element the peak capacity the equipment needs to handle. This is the capacity required for carrying the amount of traffic at the time when the sum of traffic generated by all services is highest. This requires a conversion of forecast demand to peak capacity. The network is then dimensioned to carry this peak capacity, also taking account of maximum utilisation levels and redundancy and resilience assumptions for all equipment types.

The cable network considers two types of capacities; RF Channels and Megabit per second (Mbps). This is because different network equipment is driven or its usage expressed by either of these measures.

4.1.1 Capacity requirements for voice services

The model considers different types of calls based on the information considered in the demand forecast and their use of the network. The voice minutes for each type of call are converted to capacity in the busy hour by using the following assumptions:

1. the share of traffic in the busy hour by type of service at […]% based on information from HOT and similar to the busy hour traffic in Bezeq's network;
2. adjustment for holding time of 12s and the percentage of unsuccessful calls at 23%; and
3. an uplift for variations in the level of traffic over the course of the week and year of 15%.

The latter two are based on international precedent (as a result of HOT not providing corresponding data) for uplift factors and consistent with the assumptions made in the fixed bottom-up model.

In the next step, the model determines the capacity requirement for each type of service at the different network elements. Different calls use the network differently. The extent to which a call uses different network elements is reflected in routing factors[14]. Off-net calls are generally considered to use relevant network elements once. On-net calls will generally use many network elements twice as intensively as off-net calls.

The model assumes that the bandwidth of a voice call is 98.74 Kbits per second. This is based on the use of G.711 protocol with appropriate allowance for overheads (headers and tags). Hence, multiplying the busy hour minutes with the call bandwidth for each network element gives the capacity requirements (in kbps). Dividing these totals by 1,000, gives quantities in Mbps.

A further adjustment is made to take account of the real time requirements of voice. For each network element the number of voice related Erlangs was divided by the number of network units or links to produce Erlangs per unit. A blocking rate of 0.2% was then applied to determine the actual capacity needed to ensure a satisfactory quality of service.

For the dimensioning and cost allocation of the access network, the model also requires quantifying the number of channels services occupy in the access part of the network. This is because, the requirements for RF channels is the primary driver for the use of the hybrid fibre coaxial access network. The number of channels attributable to voice is based on the basic configuration of the current cable network which rests on customer premise equipment supporting the use of 8 downstream and 4 upstream channels. The voice service is part of the traffic that is carried over these primary channels and their amount is calculated based on the voice capacity requirements (after prioritisation) as a share of total data related capacities (which in addition to voice consist of broadband and wholesale broadcasting capacities). For example, in 2015 the capacity required for voice services as calculated in the model (after prioritisation) is approximately 3.4 Gbps while other downstream and upstream traffic sharing the same groups of channels account for approximately 392[15] Gbps and 137 Gbps respectively. This

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14 A routing factor shows the extent to which different services use network elements.

15 Broadband plus multicast

results in a total number of 383 channels[16] being attributed to voice services (across all access segments in the network).

4.1.2 Capacity requirements for broadband service

As with voice traffic, busy hour broadband traffic was used for the dimensioning of core network equipment. Since average busy hour usage was provided in kbps no further transformation was required but to calculate requirements in Mbps by dividing by 1,000 and 1,000 again to arrive at Gbps. The same principle as set out for voice above is used for calculating the channels attributable to broadband. For 2015, total broadband upstream and downstream capacities in the access network of 380 and 137 Gbps respectively imply that approximately 54,000 RF channels across all access segments are attributed to broadband.

4.1.3 Capacity requirements for broadcasting and VoD services

The broadcasting capacity was calculated in Mbps and RF channels and is already that required in the busy hour due to its broadcasting characteristics, i.e. due to the nature of the service, the full capacity of all broadcasting channels is constantly required. The number of RF channels required is based on the capacities set out in section 2.2.3 and the equivalent broadband capacity of 50Mbps per 8 MHz channel but taking account of a 30% capacity reduction for overheads required when broadcasting TV channels. Based on these assumptions, the total number of channels attributed to TV (following the assumptions set out for voice earlier) is approximately 119,000 channels across all access segments in 2015.

The VoD demand is also already expressed in busy hour Mbps and no further conversion is required to calculate the total capacity. For the number of channels on the access network, the model takes into account that dedicated channels are used for providing this service (i.e. contrary to providing the service as part of the broadband data stream). The usage and capacity assumptions imply that the average busy hour usage per access segment is approximately […] Mbps in 2015 or […] concurrent VoD streams per access segment. Applying a similar prioritisation as for voice traffic implies 43 streams in the busy hour or approximately 146 Mbps or 5 RF channels. This implies a total of approximately 23,000 channels across all access segments in 2015.

16 The total number of channels considered for the dimensioning and cost allocation is based on the number of optical nodes and the number of upstream and downstream channels configured in the hardware (4 and 8 channels respectively). This results in a total of approximately 59,000 channels. across all optical nodes for 2015; i.e. 8 x 4929 = 39,432 downstream channels and 4 x 4929 = 19,716 upstream channels.

VoD demand and Cable TV content are partly considered to be provided over dedicated core network equipment while sharing the access equipment and infrastructure with broadband and voice traffic. While the second is taken into account by calculating the required number of channels on the access network (as set out above), the first is not explicitly modelled due to the fact that none of the services costed in the model are provided over the relevant types of equipment.

4.1.4 Capacity requirements for wholesale broadcast service (multicast application of BSA service).

The wholesale broadcasting capacity is equally required on a permanent basis, similar to the TV service. The calculated capacity in Mbps is therefore already that required in the busy hour. Given that the service is provided as part of those channels also used for the provision of broadband and voice services, the number of channels attributed to wholesale broadcasting is determined in the same way as for voice and broadband services. For example, the total number of channels attributed to the wholesale broadcasting services is approximately 1,100 channels across all access segments.

4.1.5 Applying the capacity requirements in the model dimensioning

The process set out above is carried out for each year individually converting service demand to capacity requirements. These requirements form the primary input to the network dimensioning, although primarily for the core network) is set out in section 4.3 after the dimensioning of the access network which is set out in the following section.

4.2 Access network dimensioning

The dimensioning of the access and core networks is based on the analysis by the Survey of Israel using GIS data of roads and buildings and locations of the headends and optical nodes in Israel. The survey was used to dimension the core and access network infrastructure (duct and trench) due to the interdependency of the two segments of the network (the dimensioning of the equipment of the core network is covered in the following section).

The survey estimates the distance between the 18 headends and the 4,553 optical nodes. We also used the estimates of the primary network measured by the survey of Israel in relation to the fixed network model, for some sharing assumptions rely mainly on types of road (inter/inner – city). The length of the access network is the length of the network to reach the customer premises where they are not already connected by the primary or secondary network.[17]

This approach implies that some of the trench considered by the Survey of Israel as secondary or primary trench is also used as access trench. This sharing is taken into account when considering the total length and cost of the access and core networks.

The data provided by the survey and further assumptions made in relation to the modelling of access and core infrastructure are set out in Table 3 below.

Table 3. Data and assumptions* considered for core infrastructure dimensioning

Parameter	Value
Length of the total core network)	6,765 km
Length of core network between municipalities (primary network)	3,711 km
Of which is the length between headends	1,096 km
Length of the network between municipalities and optical nodes (secondary network)	3,054 km
Length of the access network (links from optical nodes to customer premises)	17,497 km
Number of optical node locations	4,553
*Degree of sharing between access and primary network	5%
*Degree of sharing between access and secondary network	100%
*Degree of sharing between primary and secondary network	0%
Number of municipalities covered in the study	927

Source: Survey of Israel, SoI for the cable network model, Modelling assumptions

The assumptions about sharing have been determined in the following way:

- For the fixed network model, the *Survey of Israel*, estimated a primary trench network connecting 927 municipalities through intercity roads. We consider this estimate of the trench network as part of this model as a subset of the core trench length estimated by the *Survey of Israel* for the HOT network structure. This network leads through the municipalities, therefore covering also some of the roads that require an access network trench. However, the

17 The principles of this approach are outlined in Survey of Israel's report "Estimating Efficient Infrastructure Length, Based on Hot Telecom's Infrastructure", November 2015 (henceforth "SoI for the cable network model")

largest part of this part of the trench network would be located between municipalities without any sharing with the access network. We have therefore assumed that only 5% of the primary network is shared with the access network. This is consistent with the assumptions made in the fixed bottom-up model.

- The secondary trench network (estimated as the difference between the primary network length and the total core network length) connects the primary trench network to the optical node locations. As such, the trench is likely to be fully located in an inhabited area (i.e. given that the primary trench already leads through the municipalities) suggesting that 100% of the secondary trench would be shared with the access network. Again this assumption is consistent with that made in the fixed bottom-up model.
- Due to the principles applied when constructing the overall network (the Survey of Israel first measured the primary trench, then the secondary trench incrementally to reach the optical node location) there is no sharing between the primary and secondary trench network.

Based on the information provided by the Survey of Israel and the assumptions outlined above, the gross length of the access trench considered in the model for the base year (2015) is approximately 21,000 km. The model assumes that some degree of access network growth takes place on the basis of the historic expansion of urban roads as evident from CBS[18] data implying an annual growth of 0.8%. This growth is also considered to drive an increase in the number of optical nodes as well as the length of the secondary network linking the optical nodes with the primary network based on the ratios between the lengths of the access and secondary networks and the number of optical nodes in 2014.

The model then estimates the overlap of core and access networks and on that basis the requirements for ducts and cables. In relation to the dimensioning of the infrastructure network, the model estimates the costs of a notional network operator. This implies that infrastructure that HOT is currently renting from Bezeq is considered as an actual investment assuming the same specifications as for the rest of HOT's infrastructure network.

Further elements of the access network are estimated in the following ways:

- The model considers two duct bores for that part of the trench that is solely used for Access or Core. This assumption is based on the requirement to include in the model empty ducts for infrastructure access services. Parts of

18 Central Bureau of Statistics

the network shared between the core and access networks are correspondingly modeled using 4 duct bores (two for access, two for core).

- The requirements for coaxial cable in the network are based on the gross length of the access network and the length of coaxial cables including home wiring provided by HOT. For 2014, this equates to a ratio of approximately […] between coaxial cable and gross access trench length. This ratio is then used to estimate the length of the coaxial cable in years after 2014 given that the access network length increases over time. The type of coaxial cables is based on information provided by HOT according to which approximately 30% is used for connecting to the home and is based on RG11 type cable while the remaining length is based on 540 and 860 type cables in equal proportions.

- The model further considers amplifiers and branching points in the access network. Both are based on information provided by HOT which equate to branching points every 70m of the access network and amplifiers every 440m. The resulting number of branching points is consistent with the relatively low ratio of coaxial cable to access trench[19] while the length between amplifiers is consistent with general engineering principles also evident from information in one similar model[20].

4.3 Core network dimensioning

The volume of each type of network equipment included in the model is typically determined by the number of nodes in the network, capacity requirements and assumptions for equipment modularity, utilization and resilience. The model determines the network element requirements for any given year given these requirements and assumptions. However, the model also takes into account that the network equipment is not just brought in service instantaneously when capacity is required. We therefore take account of build-ahead requirements, i.e. investments are carried out a year prior to the network being required to meet the respective demand.

We distinguish between 4 types of network equipment as illustrated in Figure 10 earlier:

- optical nodes;

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19 A larger number of branching points enables the network operator to decrease the length of individual coaxial cables to customer premises.

20 http://danishbusinessauthority.dk/file/234415/kobber%2c_kabel-tv_og_fibre_%28dong%29_zip.zip

- CMTS and associated headend equipment (aggregators and radio frequency gateways (RFGW));
- core IP equipment; and
- infrastructure.

The following sections set out each type in more detail.

4.3.1 Optical node

Optical nodes are used to convert the optical transmission of RF channels over fiber to electrical transmission over coaxial cable for the final transmission and connection to customers. The number of optical nodes in 2014 is based on the information from the current cable network in Israel and is considered in the model on the basis of a ratio between the current length of the access network and the number of optical nodes. This implies that the number of optical nodes is gradually increasing as the coverage of the network also increases. In principle, there is also a potential need for optical nodes to increase as a result of higher capacity demands for subscribers. However, there are two reasons why we believe that this is unlikely to happen over the modelled period:

- The current number of subscriber per optical node is comparably low with approximately […] in HOT's network. For example, the model in Denmark considers an average of 350 subscribers per optical node.[21]
- According to HOT, its current network rollout principles for broadband are based on a grouping of 1,000 subscribers per downstream segment. In other words, one service group of eight RF downstream channels covers more than 3 optical nodes on average. As such, the network is able to provide further downstream capacity by reducing the number of optical nodes per downstream segment. Only after the downstream capacity requirements exceeds the capacity available from defining a single service group for every optical node may the need arise for further segmentation, i.e. splitting an optical node into two and thereby reducing the number of subscribers and hence capacity required per node.[22] Under the forecasts considered in this model, this need does not arise.

21 http://danishbusinessauthority.dk/file/234415/kobber%2c_kabel-tv_og_fibre_%28dong%29_zip.zip

22 This is only the case if the same customer premise equipment as today is used. Current cable modems support channel bonding of 8 downstream and 4 upstream channels. Future modems are planned to support 16 and 4 as well as 24 and 8 channels greatly reducing the need for further segmentation as broadband capacity continue to increase.

The number of nodes then also determines the number of coaxial segments to customers and fiber uplinks to the headend which are equal to the number of optical nodes. The model further dimensions equipment required for optical transmission and electric to optical conversion at the headend. This is covered separately for the upstream and downstream optical fiber at a ratio of 2 per upstream receiver and 4 per downstream transmitter based on the equipment modularity used by HOT.

4.3.2 CMTS and related equipment

The CMTS at the headend is responsible for managing broadband subscribers and traffic. Together with the CMTS equipment we consider equipment associated with the function of the CMTS, in particular the RFGW and the aggregator (consolidating traffic between the RFGW and CMTS).

Dimensioning the CMTS equipment

For dimensioning the CMTS equipment, the model takes primary account of the uplink and downlink traffic carried between the core and access network. The relevant capacity requirements are those for the access and the core network set out in section 2.2.2 for the downlink and uplink respectively. This is because, the CMTS equipment provides separate ports for upstream and downstream traffic and the dimensioning therefore considers the corresponding capacities separately.

The equipment is dimensioned by the number of channels required for upstream and downstream traffic. Downlink cards (cards directed towards the access network) have different channel capacities for downstream and upstream traffic. The number of cards are dimensioned according to the maximum number of channels required based on either downstream or upstream capacities. Downstream ports are connected to aggregation equipment for combining downstream broadband traffic from several CMTS. Downstream ports at the CMTS are paired for providing redundant links to the aggregator. Upstream traffic terminates directly on the upstream ports of the CMTS from the RF/optical transcoder equipment.

While the precise allocation of optical nodes to headends is not known, the model considers that headends will typically serve a varying number of optical nodes. To reflect that variability, the model attributes the populations at the locations of the current 18 headends to those headends. In addition, these headends would also be assumed to cover a share of the residual population in locations other than those with headends which is assumed to be covered by those headends in equal shares.

The number of optical nodes attributed to these headends is then based on the number of subscribers attributed to each locality (the model assumes that subscribers are proportionate to the number of inhabitants) divided by the average number of subscriber per optical node. In 2015, the number of optical nodes per headend ranges between […] and […].

Given the high density of optical nodes per headend, CMTS are modeled in combination with RFGW. This allows a greater downstream port density at the CMTS which helps reducing the costs of equipment at the headend. The ports of the corresponding port cards are shown in **Table 4** below.

Table 4. CMTS – downlink port card specification

	CMTS with RFGW
Number of physical upstream ports	20
Number of physical downstream ports	3
Number of RF channels per upstream port	3
Number of RF channels per downstream port	24

Source: Cisco

Based on this, a CMTS assuming one spare port card slot for redundancy is able to provide 504 downstream channels in a with RFGW and 140 without. For upstream, the number of channels are 420 and 140 with and without RFGW respectively.

The corresponding number of CMTS chassis are calculated in 5 steps:

- The number of upstream and downstream channels and corresponding number of physical ports are driven by the total capacity requirement generated by the optical nodes connected to a headend. This is driven by the number of subscribers and the volume of upstream and downstream access capacity per subscriber. For example, in 2015, the upstream and downstream access capacity per subscriber is 0.13 and 0.36 Mbps[23] respectively (covering both, voice and data services). The total upstream and downstream capacity at a headend connecting 316 optical nodes is approximately 9.5 and 26.3 Gbps respectively.

- The example above implies a notional number of upstream and downstream channels of approximately 352 and 526 respectively assuming a capacity of 27 and 50 Mbps per RF channel. These capacities are based on the

23 This is expressed as a capacity per connected subscriber (not connected voice or broadband subscriber) and therefore different from the service specific capacities mentioned earlier in this documentation.

assumption that a newly deployed cable network is capable of operating at 64 and 256 QAM on channels of 6.4 and 8 MHz bandwidths, upstream and downstream respectively.

- 4 and 8 upstream and downstream channels form a single upstream and downstream service group respectively and can provide services to several optical nodes per service group (independent for upstream and downstream). Because of that, the numbers of channels calculated in the previous step need to be adjusted to take into account that service groups cannot be attributed to a fraction of an optical node. I.e. the number of optical nodes per service group based on the notional number of channels may be 4.5. This means that the number of channels must be adjusted in such a way, that the maximum number of optical nodes per service group doesn't exceed 4. Based on the example set out earlier, the increase in the number of channels in 2015 is approximately 20% for upstream and downstream, resulting in a total of 424 upstream and 632 downstream channels.

- Based on the dimensions of the CMTS equipment, the number of these channels drives the number of physical ports required. For example, based on the channels calculated above, the number of physical ports required are 142 for upstream and 27 for downstream. Based on the technical dimensions of the port cards considered, the card requirements are 8 based on upstream and 9 based on downstream. The maximum of the two drives the total number of slots required (i.e. in the case above 9). This is because upstream and downstream ports are provided on the same card.

- Finally, the total number of required slot cards drives the number of CMTS chassis. Based on the example above, a single chassis is required based on the maximum number of slots of 8 assuming that one slot remains empty for redundancy.

- Further steps involve the dimensioning of uplink cards to IP equipment which is based on the total downstream capacity required.[24] The model uses the core downstream traffic as upstream will typically be less than downstream and transmission links in the core network are bidirectional providing the same capacity up- and downstream.

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24 Taking account of a maximum utilization rate of 80%, which is equal to the widely accepted utilization rate of core network equipment.

The equipment considered for headends, consistent with the current cable network, includes three additional types of equipment prior to the fibre optic downlink to the optical nodes:

- Aggregator: Aggregation equipment at the headend consolidates downstream ports from the CMTS equipment. This is appropriate given the downstream output ports at the CMTS (1GE) are of a lower capacity than the downstream input ports at the RFGW (10GE). The aggregator is dimensioned according to the number of 1 and 10 GE ports to CMTS and RFGW and based on the modularity of equipment currently used in the cable network in Israel.

- Radio frequency gateway: The RFGW consolidates downstream channels prior to transmission over the hybrid fiber coaxial network. The modularity and equipment set out in the model is based on current equipment in the cable network in Israel. In line with manufacture specification, all RFGW are fully equipped with port cards regardless of utilization. However, the total number of RFGW is still based on the requirements of upstream and downstream ports and channels although the requirements for the modelled network and period do not exceed one RFGW per headend location.

- Separate CMTS and RFGW also imply a requirement for additional equipment for the provision of the DOCSIS timing interface. This is provided by two DTI servers per headend location where the second server is provided for backup.

Table 5 below sets out the number of assets considered in this section over the period of the model (after taking account of build-ahead requirements).

Table 5. CMTS and associated equipment in headends

	2015	2016	2017	2018
CMTS	34	48	84	84
RFGW	19	19	20	20
Aggregator	18	18	18	18
DTI	36	36	36	36

Source: HFC model

4.3.3 IP routers

IP routers at the headends are responsible for handling traffic between headends by linking edge IP routers to a set of core IP routers. Core IP routers are meshed as well as connected to other types of service specific equipment, such as voice switches and interconnect with other operators, e.g. ISPs.

Every headend has one or more IP routers to transmit broadband and voice traffic. VoD and HOT's TV traffic is assumed to be carried over separate equipment. A scenario for an all IP provision of services might be reasonable to consider in a future version of the model given that equipment vendors aim to offer convergence solutions while operators are seeking to simplify their network structure. However, given the lack of corresponding precedent of all IP cable networks suggests that rolling out an all IP network does not yet represent a viable option.

Based on the information provided by HOT at the end of 2014 on the actual cable network in Israel, the model considers the same type of equipment for the edge and the core.

- Edge routers: The model dimensions the edge routers (i.e. the chassis and ports) to be able to handle the traffic and ports for downlinks to CMTS and uplinks to core IP routers In 2015, the model estimates a total of 18 edge routers, one per headend.

- Core routers: The model estimates core routers based on the requirements for uplinks from edge routers and the assumption that core routers are fully meshed but also the assumption that at least 3 core router sites are required for resilience and interconnection. Based on the 2014 to 2018 demand and modelled edge routers, the model does not estimate more than three core routers for the entire model period. These are assumed to be located at different headend sites.

As for CMTS, edge and core routers are dimensioned according to the number of ports and hence port cards and port card slots required. Each edge router terminates a number of 10GE downlinks from CMTS taking into account resilience; i.e. each CMTS links to two edge routers. The number of uplinks to core routers is driven by the amount of core capacity required[25], i.e. further aggregating the capacity provided over the edge router links and the resilience assumption of one edge router linking to two core routers. The port requirements of core routers are driven by the number of those links and the number of cross links to other core routers assuming that core routers are fully meshed. The number of ports drives the number of port cards assuming a total number of 24 10GE ports per port card. The number of port cards then drives the number of chassis assuming a maximum of 7 available slots, assuming one slot is kept as spare.

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25 Again taking into account a maximum utilizations rate of 80%.

Table 6 below sets out the number of edge and core IP routers as well as port cards estimated in the model (after taking account of build-ahead requirements).

Table 6. IP edge and IP core router

	2014	2015	2016	2017	2018
Edge IP router	18	18	18	18	18
Edge IP – port cards*	20	23	29	41	41
Edge IP router	3	3	3	3	3
Core IP – port cards*	3	4	6	7	7

Source: HFC model

* The number of port cards in the edge router increase significantly as a result of the increase in the number of CMTS. The port cards in the core router increase as a result of the significant increase in data traffic.

4.3.4 Infrastructure

The final step in modelling the core network covers the dimensions of the infrastructure connecting the various nodes in the core network. The dimensioning of the network is again based on the analysis carried out by the *Survey of Israel*.[26] Based on this information, the total core network distance is 6,765 km in 2014. The data provided by the survey and further assumptions made in relation to the modelling of core and access network infrastructure are set out in Table 7 below.

Table 7. Data and assumptions* considered for core infrastructure dimensioning

Parameter	Value
Length of the network between headends	1,096 km
Length of the primary network (major roads between municipalities)	3,711 km
Length of secondary network (links from the primary roads to optical nodes)	3,054 km
Optical node locations considered for estimating length of secondary network	4,553
Number of municipalities covered in the study	927
***Degree of sharing between access and primary network**	5%
***Degree of sharing between access and secondary network**	100%
***Degree of sharing between primary and secondary network**	0%

Source: Survey of Israel, Survey of Israel for the cable network model, Modeling assumptions

26 Survey of Israel's report "Estimating Efficient Infrastructure Length, Based on Hot Telecom's Infrastructure", November 2015

The assumptions about sharing are those already set out in section 4.2. These distances and information on the number of nodes in the network are then used to attribute the costs of the network to different segments of the access and core network (i.e. the link between optical nodes and headend and distances between headends and master headends). The model calibrates a function and parameter for calculating the trench distance between different elements of the network based on the total distance between optical nodes (6,765 km for 4,553 locations). The corresponding distances between nodes for 2015 based on this function and other information and are set out in Table 8 below.

Table 8. Network length between different layers of the network (2015)

Network segment (source of length)	Length of network between nodes
Optical nodes (sum of primary and secondary network)	6,790 km
CWDM nodes (function based on core network length for optical nodes)	4,023 km
Headends (SoI estimate)	1,096 km
Master headends[27] (core IP nodes in fixed network model)	326 km

Source: HFC model

These distances provide the basis for allocating the total core network distance and corresponding duct to the individual network segments. This takes into account that different functions of the network overlap. The corresponding allocations are outlined in Table 9 below.

Table 9. Allocation of duct and trench to network segments (2015)

Network segment	Allocation
Optical node to headend	91.1%
Headend to Master headend	7.3%
Master headend to Master headend	1.6%

Source: HFC model

27 Master headends are those headends where core IP equipment is located

Consistent with the assumptions made for the access network, the number of ducts in the core network is two in areas where the trench is solely used for the core network and four where the trench is shared with the access network.

Fiber cable types and lengths are estimated based on the number of uplinks and downlinks from each network segment and the number of nodes of individual network equipment. The model takes into account how the different uplink and downlink requirements overlap to estimate the total thickness of cables. This is also based on the length of roads between different segments outlined in Table 8 above. The corresponding lengths and distribution of cables to network segments in 2015 is outlined in Table 10 below.

Table 10. Fiber cable length and allocation (2015)

Cable size	Cable length (km)	Optical node to Headend	Headend to Master headend	Master headend to Master headend
24	5,711	100%	0%	0%
48	1,080	100%	0%	0%
96	452	100%	0%	0%
144	785	0%	100%	0%
288	333	0%	0%	100%

Source: HFC model

4.3.5 Transmission equipment

The small number of headends and the large number of optical nodes per headend imply that the distances between headends and optical nodes are likely to be longer than what can typically be covered by point to point fiber connections. The model therefore considers CWDM equipment connecting the headends to approximately 700 optical nodes with remote CWDM equipment from which direct point to point fiber is deployed to the remaining optical nodes in the network. This equipment is also driving the number of fiber cables required between optical nodes and headends based on 8 frequencies being transmitted over a single fiber.

4.3.6 Support equipment

The final elements considered in the network are those required for supporting the primary network equipment outlined above. The model takes into account power supply, backup power, air conditioning, security and site preparation. This is based on the number of headends and core IP location. The equipment is not estimated as such, but the costs provided by HOT, which were reconciled against the normative costs used in the fixed model, are divided by the current number of headends to calculate an average costs which is then applied to the modeled number of headends. Further detail on this is provided in section 5.

4.4 Network dimensioning outputs

The model generates for each year of the modelled period a list of infrastructure and equipment units consistent with the demand and corresponding capacity requirements for that year. In accord with best practices and TSLRIC methodology, prior to applying unit capex and operating costs, the model takes into account a build ahead requirement of one year which implies that the costs in the current year are driven by the equipment and infrastructure demand of the following year. The corresponding equipment units are then considered in the network and service costing section of the model, the details of which are discussed in the following sections.

5 Network costing

The next step in the modelling process is the calculation of total network costs based on the equipment and infrastructure quantities estimated in the model. The process follows 4 steps:

- calculating annual gross replacement costs;
- calculating annual operating expenses;
- annualizing gross replacement costs; and
- calculating total annual costs.

The inputs to this process are primarily based on the current cable network in Israel, complemented where necessary with information from other jurisdictions and assumptions taken in the fixed bottom-up model considered in MOC Decision.[28] For example, this is the case for input costs, such as trenches, ducts and fibres that are equivalent across both types of networks.

5.1 Calculating gross replacement costs

The gross replacement costs include acquisition and installation costs of the equipment and infrastructure set out in section 4 of this document. The majority of the cost inputs to the model are based on information from the current cable network in Israel. While often inconsistent and in formats different from those requested from HOT, the information provided was sufficiently extensive to be able to reliably populate most elements of the costing part of the model when it was found to correspond with costs incurred by an efficient operator. Data on cost had been received on a number of occasions between 2011 and 2014. Where possible and sufficiently comprehensive, the most recent data was used. Hot also provided, to our and MOC's demands, further clarifications and explanations to the data it provided. Hence, the cable network model relies less on benchmark data than the fixed bottom up model.

The following table sets out the data used in the model, the year to which it relates and the assumptions applied in relation to installation.

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28 Final decision concerning wholesale services rates in Bezeq's network, dated 17.11.14. available at http://www.moc.gov.il/sip_storage/FILES/0/3960.pdf

Table 11. Infrastructure and equipment cost inputs

Infrastructure / equipment	Year of cost information	Source	Acquisition (NIS)	Installation (NIS)
Trench	2014	2 Israeli operators / consistent with assumption in fixed cost model	178,023	
Duct	2014		12,100	
Coaxial cable, branching points and amplifiers	2012 2013 2013	HOT	Coaxial cable […]* Branching point […]* Amplifier […]*	
Fiber cables	2013	1 operator in Israel and 1 confidential source / consistent with assumption in fixed cost model[29]	Cable - ducted 24 fiber 11,228 Cable - ducted 48 fiber 12,211 Cable - ducted 96 fiber 15,301 Cable - ducted 144 fiber 16,235 Cable - ducted 192 fiber 21,156 Cable - ducted 288 fiber 21,310	
Optical node	2014	HOT	Cabinet […]	
			Transceiver^ […]	20%
Optical transmitter and receiver (HE)	2014	HOT^	Transmitter […] Receiver […]	20% 20%
CMTS	2013	HOT^	Chassis - […] Port cards – […]**	20%
RFGW	2013	HOT^	Chassis - […] Port cards - […]	20%
Aggregator	2013	HOT^	Chassis - […]	20%
DTI	2013	HOT^	[…]	20%
IP edge / core router	2014	HOT^	Chassis - […] Module - […] Ports - […]	20%
Support costs Headend (CMTS / RFGW / IP)	2012	HOT	Power […] Backup power […] Air conditioning […] Site preparation […]	

*averages of several types of equipment

^Acquisition costs based on HOT excluding installation. The installation mark-up has therefore been based on the assumptions for core network equipment used in the fixed network model.

** additional costs apply based on the number of ports being utilized

29 Fiber jointing costs are based on Danish BU model; consistent with assumptions in fixed BU model.

We made a number of observations in relation to the cost data provided by HOT:

- CMTS/RFGW and associated equipment prices also vary significantly in the data provided by HOT. Cost information provided for 2011 and 2013 differs significantly. Information provided in 2014 is again different from those costs previously provided for 2011 and 2013. We have therefore compared this information against costs of equipment in the Danish bottom-up model and found that all three data points are lower compared to those costs. The 2014 cost information is significantly higher and does not allow to extract the actual discounts HOT may have received over the listed prices, and hence using the 2014 prices would result in gross overestimation of network costs. We therefore use the 2013 information in the cable network model.

- Support costs are not based on individual equipment units but rather based on the costs provided by HOT for the overall functions in its network. These costs have then been attributed in equal amounts to individual equipment in headends which results in costs being similar to those considered in the fixed BU model except for site preparation costs which are significantly higher. This is likely to be the case because site preparation as provided by HOT also includes the space required for equipment not considered in the model (such as VOD, Broadcasting and voice specific equipment). We have therefore chosen the site preparation cost of IP core equipment as considered in the fixed BU model. This is reasonable because the size and amount of equipment is more similar to fixed core IP than aggregation or IP edge equipment which is more numerous in fixed networks and therefore typically smaller and less costly in relation to site preparation.

Based on the assumptions and inputs set out above, the model calculates total gross replacement costs by multiplying the acquisition and installation unit costs with the units estimated in the network dimensioning part of the model. The gross replacement cost for each equipment and infrastructure is then considered for the calculation of operating expenses and the annual capital costs. This is set out in the following sections.

5.2 Estimating operating expenses

Operating expenses are primarily based on information provided by HOT in relation to specific network equipment. The model considers mark-ups applied to gross replacement costs calibrated to match the 2013 modeled operating costs with the information provided by HOT for the years 2012 and 2013. The corresponding mark-ups and total operating expenses have been compared against the operating expenses determined in the fixed model. While some of the mark-ups are above those considered in the fixed model they typically result in total costs that are lower than those derived in the fixed model. This is because the acquisition costs of most of HOT equipment are typically below that of the equipment in the fixed model and therefore the operating expenses are correspondingly lower. We therefore consider the ratios applied on the basis HOT as a reasonable basis for an efficient cable operator.

The corresponding mark-ups together with additional direct operating assumptions such as power and space requirements are set out in Table 12 below

Table 12. Operating cost assumptions

Infrastructure / equipment	Operating cost mark-up (% of GRC)	Power (kwh / year)	Aircon (max watt per sq. m)	Space (m^2)
Trench	0.5%			
Duct	0.5%			
Coaxial cable	2%	625/km		
Amplifiers/Branching points	2%			
Fiber cable	8%			
Optical nodes	6%	139		0 – 0.1^
Transmitters		277.44	316.71	
Receivers		139	158.36	
DTI	20%	2,500	570.78	0.5
Aggregator	20%	5,500	627.85	1
CMTS / RFGW	20%	13,140	300 / 375	4 / 5
IP equipment	20%	13,140	1,219	1
Support equipment	15%			1 – 5

^optical nodes are assumed to be deployed exclusively in outdoor cabinets and therefore do not incur any costs for space above and beyond the costs of cabinets. Optical transmission equipment at the headend however does require corresponding accommodation.

The Gross Replacement cost (GRC) multiplied with the operating cost mark-up represents the ongoing maintenance costs attributed to the corresponding equipment or infrastructure. The annual power consumption, air-conditioning and accommodation requirements for each type of equipment are multiplied with costs of 0.56 NIS, 6.64 NIS and 977 NIS respectively; consistent with the assumptions in the fixed network model.

5.3 Annualizing gross replacement costs

In setting regulated prices, investment costs need to be recovered over the period the assets generate revenues for the company, rather than in the year the cost was incurred. We applied "annuity" and "price tilted annuity" formulae to establish the annual cost of assets in each year of the modelled period.

The standard annuity formula is applied to passive infrastructure assets reflecting their importance as bottle-neck infrastructure and the fact that access seekers are unlikely to seek to establish a parallel infrastructure in addition to those operated by HOT and Bezeq.

The annuity formulae are used to set a general path for returns (R) on an investment (I) over the life of the investment (N years). Overall, the initial investment must be equal to the Net Present Value (NPV – the left hand side of the equation) of returns over time:

$$\sum_{t=1}^{N} \frac{R_t}{(1+r)^t} = I$$

For active network equipment (such as routers) a **'tilt'** is applied at the rate of equipment price changes. This takes into account that such equipment costs will typically decrease over time.

An annuity with a tilt therefore provides the same NPV over the life of the assets but with the profile of that compensation falling over the life of the asset. The formula for the price tilted annuity applied in the model is as follows:

$$R_t = V \frac{r - trend}{1 - \left(\frac{1 + trend}{1 + r}\right)^{years}}$$

where ***r*** is the cost of capital[30] and *trend* the equipment specific price trend and V the gross replacement costs of the assets.

A price tilted annuity formula was used to ensure an equal spread of costs of equipment across years with a focus on recovering costs in earlier years if the price of that asset is expected to decrease and in later years if the price of the

30 The determination of the cost of capital (WACC) is set out in Frontier Economics: "Estimating the Cost of Fixed call Termination on Bezeq's Network", October 2013, Available at http://www.moc.gov.il/sip_storage/FILES/3/3383.pdf. For applying the WACC used in the FTR decision in the cable network model, see Levaot - Gronau Recommendations concerning wholesale services pricing over Hot's network.

asset is expected to increase. This reflects the competitive pressure an operator would face if alternative operators entered the market at any given point of the modeled period, purchasing equipment at prices expected for that period

For the equipment employed in the cable network, we assume the following price trends and economic lifetimes as outlined in Table 13.

Table 13. Equipment / infrastructure price trends (real[31])and economic lifetime

Equipment / infrastructure	Price trend	Economic lifetime
Infrastructure (coax)	0%	30 (15 for amplifiers)
Infrastructure (duct, trench)	0%	40
Infrastructure (fiber)	-2.56%	25
Optical nodes / equipment	-2.56%	8 (15 for the cabinet)
CMTS/RFGW	-2.56%	8
IP	-2.56%	8
Support	-2.56%	15 (30 for site preparation)

For calculating annualized capital costs, the model multiplies the gross replacement costs of each network element with the price tilted annuity factor for that element.

5.4 Calculating total annual costs of network equipment and infrastructure

The final step in the network costing section of the model considers common and indirect operating expenses. These are based on information from HOT and are expressed in the model as a mark-up to direct annual capital and operating costs at a level of 13.8%. In other words, common and indirect costs are attributed to network equipment based on an equi-proportionate mark-up prior to network cost allocations to services. While this mark-up is higher than the one applied in the fixed model (10%), the total overhead for the cable network is approximately NIS 40m lower than that estimated for the fixed network. This is

31 The price trend for trench and coaxial cable is set to zero following the principle of constant input prices and standard annuity depreciation for passive infrastructure.

because the level of capital investments for the cable network is significantly lower than those for the fixed network. As overhead costs are unlikely to be directly related to the technology of the network which leads to those differences in costs we consider that the higher mark-up are reasonable for the cable network.

The sum of operating, annual capital and attributed common and indirect costs are then allocated to services. This is set out in the following section.

6 Service costing and model results

The final step in the modelling process is to allocate total annual costs of equipment and infrastructure to services. This section outlines the steps involved in this calculation by first setting out the process of cost allocations followed by an overview of the calculation of final wholesale service costs.

6.1 Cost allocation

In cases where a particular type of equipment is solely used to provide a single service, its costs can be directly attributed to this service. However, in cable networks, consistent with other telecommunication networks, equipment and infrastructure are used to provide a range of different services. Hence, the cost of this equipment and infrastructure needs to be attributed between those different services. The model attributes these costs according to the intensity with which a particular type of equipment is used by different services. For example, the fiber links between headends and optical nodes provide transmission for voice, data and broadcasting services. Therefore, the costs for fiber and associated infrastructure and equipment are allocated to the different services relative to their utilization of the links.

The allocation of costs to services is done in 4 steps:

- The costs of equipment and infrastructure are mapped to those network categories for which a set of routing factors are applied. I.e. there are fewer network categories than equipment and infrastructure elements in the dimensioning part of the model.
- Each modelled service has a set of routing factors across all network categories according to its utilization of the network elements.
- The demand for all services are multiplied with their respective sets of routing factors to determine the total service volume for each network category and finally network category unit cost.
- The final allocation of costs to wholesale services is then based on the consumption of a single wholesale service of these network category units, again set out by the routing factors for a particular service.

The calculation and results for the final wholesale services are set out in the following section.

6.2 Wholesale service costing

The HFC model estimates the costs of the following wholesale services:

- bitstream transport;
- wholesale subscriber access, and
- wholesale broadcasting transport.

The cost estimate for the bitstream transport service includes the costs of the optical node and optical fiber network to the headend as well as the CMTS and associated equipment and core IP equipment. The cost is estimated on a per Mbps basis. Based on the steps set out in the previous section, Table 14 sets out the costs attributable to the bitstream service in 2015.

Table 14. Bitstream service costs, core element (NIS / Mbps – 2015)

Network element	Total annual cost	Total network volume (Gbps)	Network unit cost (NIS / Gbps)	Broadband service volume (Gbps)	Broadband unit cost (NIS / Mbps)
Optical node	13,567,399	0	0	0	0.00
DTI	1,123,626	477	2,357	462	3.61
Aggregator	888,326	477	1,863	462	2.85
RFGW	9,167,001	477	19,225	462	29.43
CMTS: Downlink	3,281,577	477	6,879	462	10.53
CMTS: Processor	4,160,848	477	8,722	462	13.35
CMTS: Uplink	2,247,278	304	7,391	302	7.39
Edge router: Downlink	4,564,613	304	15,014	302	15.01
Edge Router: Processor	3,256,328	304	10,714	302	10.71
Edge Router: Uplink	4,113,787	304	13,535	302	13.54
Core Router:Processor	490,571	304	1,615	302	1.62
Core Router: Core Router	1,890,146	304	6,223	302	6.22
Transmission - Coaxial cable	457,019,184	0	0	0	0.00
Transmission - ON to HE	110,513,545	0	0	0	0.00
Transmission - HE to MHE	10,350,377	740	13,992	302	13.99
Transmission - MHE to MHE	2,628,258	739	3,555	302	3.55

The total core network cost per Mbps based on the table above is around NIS 132. The service also takes into account the costs attributable to channels for carrying broadband services between the optical nodes and headends. The total cost added for this element once converted to Mbps is NIS 112 per Mbps. Finally, applying wholesale specific cost mark-ups of 5.3%[32] to the above cost elements calculates total annual costs per Mbps of around NIS 254 in 2015 or 21.37 NIS per Mbps per month.

The cost estimate for the wholesale subscriber access includes the passive infrastructure between the optical node and the customers and is expressed as a

32 The wholesale specific mark-up is based on the assumptions in the fixed bottom-up model.

cost per subscriber by dividing the total costs by the number of unique subscribers on the current cable network.

The cost estimate for the wholesale broadcasting transport service includes the same elements as the bitstream transport service but takes into account that the service must be provided simultaneously on all core network elements and fiber links to the optical nodes. These costs are also estimated on a per Mbps basis.

Costs for wholesale subscriber access and wholesale broadcasting transmission are derived in the same way as for bitstream transport by applying the routing factors specific to those services and wholesale specific mark-ups as set out above. The set of costs for the period of 2015 to 2018 for the services calculated in the HFC model are outlined in Table 15 below.

Table 15. Summary of estimated service costs (NIS / month)

	Unit	2015	2016	2017	2018
Wholesale access	Access	37.14	38.68	40.30	41.71
Bitstream transport	Mbps	21.37	16.68	13.64	9.46
Broadcasting transport	Mbps	9,996	9,997	11,180	11,883

Annex: benchmark model references

This annex lists the sources of models used as benchmarks in the development of the fixed bottom-up model in Israel:

Denmark:

- http://erhvervstyrelsen.dk/gaeldende-pris
  Version 4.23 of the models (core, access, co-location and consolidation) can be accessed by going to 'LRAIC fastnet', followed by 'Gaeldende prisagorelse for 2014' followed by 'Modeller (zip)'.

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