Evaluation of Power Rating of Core Network Equipment in Practical Deployments

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***Abstract*—Reasonably accurate reference power consumption values are required for any work that evaluates power consumption in telecommunication networks. Many existing works provide or use optimal power rating (W/Gbps) values, i.e. the power rating achieved for the maximum capacity of the system, with the shared relative overhead thus being the smallest. In this paper, we evaluate how power rating values are influenced by practical equipment filling levels for core IP-over-WDM equipment. We show that, over the equipment's lifetime, for IP/MPLS routers it is reasonable to almost double the optimal power rating value under real-life equipment filling conditions. For Optical Line Amplifiers a correction factor of 1.5 is appropriate, and for WDM terminals the required correction is almost negligible, i.e. 1.1. Furthermore, power measurements on IP routers and Optical Line Amplifiers show that their power consumption marginally depends on traffic load.**

I. Introduction

Network power consumption estimations are often based on optimal power rating values — Research into the reduction of power consumption of telecommunication networks is thriving. Over the last years, numerous studies have been conducted that either estimate current or future power consumption of telecommunication networks, or that evaluate power-saving techniques. A key input for these studies are, obviously, power consumption values for the constituting equipment like routers, transponders and inline optical amplifiers. In many works the power consumption values are based on *optimal* power rating (W/Gbps) values. This is especially the case for studies that determine the power rating using a top down approach, such as the analytical path-based models in [1], [2] and [3]. Power rating values express equipment power consumption as power per capacity, e.g. 10 W/Gbps [1]. These power rating values are optimal in the sense that the power consumption is determined based on the maximum capacity of the system, with the shared relative overhead thus being smallest.

It is currently unclear how much these power rating values vary over real-life product deployments and lifetimes, and with varying traffic load — However, equipment deployed in the field is not always optimally filled, but instead starts off with an almost empty chassis which is over time filled with more line and control cards. As a result, power rating values will only approach their optimal value near the end-of-life of the equipment, when the chassis overhead is shared by the maximum number of functional components. In addition, since the power rating is based on the power per capacity, the influence of power scaling with varying traffic load (throughput) is not captured in the power rating value. Most equipment does however consume less power, even if only slightly so, under reduced traffic load.

Contributions of this paper — How does the power rating value scale during the equipment lifetime, and can we derive an average correction value given typical equipment lifetimes? This is the question we try to answer in this work. We focus separately on Internet Protocol (IP) routers (Section III-A), Wavelength Division Multiplexing (WDM) terminals (Section III-B) and Optical Line Amplifiers (OLAs) (Section III-C). The influence of traffic load on IP and WDM equipment power rating is only briefly considered in this paper (Section IV); initial results suggest that this is a promising topic for future work.

We focus on core network equipment only. While the access networks currently consume by far the highest share of the total energy needed by the telecommunication networks, with rising traffic volume the share of core network power consumption is expected to increase considerably [1][4]. In a narrow sense, the results of this paper provide correction factors to refine our earlier power consumption and power rating values reported in [3]. In a broader sense, we try to see whether or not current equipment system architectures can be optimized for energy efficiency.

In this paper, we will use the term *power rating correction factor* to express any deviation from the optimal power rating. We define it as the ratio (≥ 1, by definition) of a power rating at a specific condition (e.g., filling level, point in time, or given traffic load) to the optimal power rating. We are not particularly interested in the power rating values (in W/Gbps) themselves, as they are based on our earlier work in [3] except for the power consumption values of WDM terminals in Section III-B — we also introduce power consumption values for 40G and 100G coherent transponders that are not available in [3].

[1] In some other works, including our earlier work [3], the term *power efficiency* is used for denoting W/Gbps values. However, this is slightly unfortunate terminology, as higher values of power efficiency indicate higher power consumed per Gbps, whereas the term suggests the opposite. Therefore, we will use the term *power rating* consistently in this work when referring to W/Gbps values.

II. Related work

We first look for the metrics assessing power efficiency of network devices. An overview of the power rating of network devices in different configurations is performed next. The aim of this survey is to gather information related to evaluation of power rating of IP and WDM network devices with respect to the equipment filling, and traffic load.

A. Quantification of power efficiency

As indicated in Section I, power rating is used in the emerging models estimating power consumed by telecommunications networks. The generic terms power efficiency, energy efficiency, etc. can be interpreted in different ways. An overview of the green networking metrics is provided in [5] together with a case study on profiling router energy consumption using the metrics Telecommunications Energy Efficiency Ratio (TEER), Telecommunications Equipment Energy Efficiency Rating (TEEER), Energy Consumption Rating (ECR) and Energy Efficiency Rating (EER).

The Absolute Energy Efficiency Metric proposed in [6] provides a metric (in $dB\varepsilon$) to express the energy efficiency of any information processing device (be it an ICT network system, a computer or human brain) relative to the theoretical minimum energy dissipated to process a bit. It is logarithmic-based to deal with the large order of magnitudes of difference with respect to this lower bound.

Reference values for power consumption and power efficiency (in W/Gbps) were proposed in our previous work [3]. The proposed values however do not take into account equipment filling and load dependency. Capacity (bit rate) of the network devices, and not the actual throughput were used to calculate the reference values.

B. Power rating of network devices in various configurations

Chabarek et al. [7] measured power consumption of two Cisco routers in different configurations and under various loads. They observed that while the configuration (chassis and line cards used) significantly influences the power consumption of the router, the load has limited impact. These observations are confirmed in [8].

Dependence of power consumption of servers on load (idle or full) is reported in [9] together with its evolution over time. Moreover, an analytical model for determining the influence of renewal rates of servers on the carbon footprint is presented, taking into account that new servers are more energy efficient and have higher processing capacity, but that manufacturing of servers contributes to the carbon footprint as well.

Similarly, power consumption and processing capacities of modern IP and WDM devices change over time. Depending on the changing (in the long-term) traffic demands, their configuration evolves, and eventually they need to be replaced by new (more energy-efficient) equipment. We address the configuration evolution in this work, and use the term "equipment filling" in this context, which is, to the best of our knowledge, a novel aspect in the field of green networking.

III. Influence of equipment filling levels on power rating

A. IP routers

We considered a single chassis configuration for a Cisco CRS-3 and a Juniper T1600 router to determine realistic power rating values for IP routers in operation. Following the same equipment breakdown as in [3], we started from an empty basic node, and gradually filled the chassis with slot and port cards. We took the typical power values for the basic node, slot and port cards from [10] (which itself is based on product data sheets). One component contributing to the basic node power consumption is the chassis internal cooling. We considered the power drawn by the internal cooling to be fixed over the complete router chassis filling range. This is because the internal cooling power is probably influenced more by the premises temperature than the filling level. We assumed this based on the vendor statement in [11] that 'fans running at full speed [are due to] high temperature environment or cooling component failure'. This is confirmed in [12] for Internet Service Provider Points of Presence. In any case, we show near the end of this section with a short case study that the impact of internal cooling power scaling is very small and can be neglected in this context. Furthermore, we assumed port cards capacities (14x10 Gbps and 4x10 Gbps, respectively) that fit exactly the maximum slot capacity (140 Gbps and 40 Gbps, respectively). The resulting total power consumptions and derived power ratings are shown in Table I and Table II.

TABLE I
CRS-3 (single chassis) power consumption and power rating for increasing capacity (table trimmed to save space)

Basic Node [Watt]	Slot/port card count	Slot&port card power [Watt]	Total power [Watt]	Total capacity [Gbps]	Power rating [W/Gbps]
2401	1/1	536	2938	140	21.0
2401	2/2	1073	3474	280	12.4
...	...	...	...	...	...
2401	15/15	8046	10447	2100	5.0
2401	16/16	8582	10984	2240	4.9

TABLE II
Juniper T1600 (single chassis) power consumption and power rating for increasing capacity (table trimmed to save space)

Basic Node [Watt]	Slot/port card count	Slot&port card power [Watt]	Total power [Watt]	Total capacity [Gbps]	Power rating [W/Gbps]
1719	1/1	547	2266	40	56.7
1719	1/2	607	2326	80	29.1
1719	2/3	1154	2873	120	23.9
...	...	...	...	...	...
1719	7/14	4246	5965	560	10.7
1719	8/15	4793	6512	600	10.9
1719	8/16	4853	6572	640	10.3

1) Power rating as a function of the filling level: Based on the values in Table I and Table II, Fig. 1 shows the power rating correction factor for increasing filling of the router chassis. As

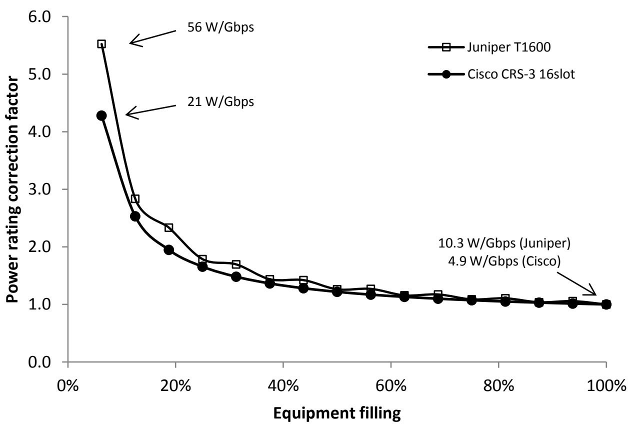


Fig. 1. IP router: power rating correction factor (relative to the best power rating) as a function of the filling level of the basic node with slot and port cards.

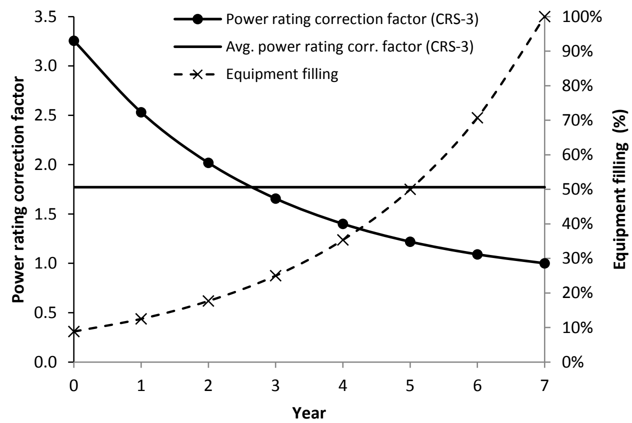


Fig. 2. IP router: CRS-3 power rating correction factor (left axis) and relative equipment filling (right axis) evolution over time.

can be seen, the power rating starts off as being 4 to 6 times worse than the optimum, when the chassis only contains one slot and port card, and gradually improves as more cards are added, until it reaches its optimum value when the chassis is fully filled. The results for both routers align quite nicely, with the Juniper router having a slightly worse power rating correction factor at lower filling levels. The bumps in the Juniper T1600 curve are due to the fact that the slot cards can hold two port cards, thus gradually filling the shelf results in an extra slot card every two port cards. In contrast, each slot card holds only one port card in the Cisco configuration.

2) Power rating evolution over time: Fig. 1 does not give an indication about the resulting average power rating of equipment deployed in the field. For this, we need information on the distribution of equipment filling levels of deployed equipment. Given the current and forecasted IP traffic increase of 40%-50% per year ([13], [14]), it makes sense to assume that equipment deployment will follow the same trend. We assume that the amount of hardware deployed doubles roughly every two years, adding cards, shelves and bays until the end of the life of equipment, when it is completely filled. This corresponds to a Compound Annual Growth Rate (CAGR) of 1.41. Depending on vendor and operator strategies, there can be large variations on actual lifetime (sometimes as short as 3 years) and final filling rate. We estimate the end of life to be around 8 years for WDM systems. For IP routers the lifetime is less clear-cut. As a first-order estimation, we assume the same lifetime for IP routers as for WDM equipment, i.e. 8 years.

Assuming the growth rate and lifetime given above, we can calculate the filling level (with respect to the maximum filling level) over these 8 years. The initial filling level is taken such that given the growth rate, the end-of-life filling level is 100%. The result is indicated in Fig. 2 (right axis).

If we combine this filling level evolution with the information in Fig. 1, we can also determine the evolution of the power rating correction factor over time. This is indicated in Fig. 2 (left axis) for the CRS-3. The T1600 curve (not shown in Fig. 2) is very similar. If we assume an equal amount of equipment being deployed in each of the 8 phases, we can calculate the average power rating correction factor. For the considered CRS-3 this average power rating correction factor is 1.77 and for the T1600 1.92 (the latter value not shown in the figure). This means that the power rating of deployed core routing equipment is on average nearly twice the power rating at the optimum filling. This is inline with our earlier statement in [3] where for the best core router power rating of 5.5 W/Gbps we proposed to use 10 W/Gbps to correct for 'suboptimally filled configurations', since 5.5 W/Gbps $\times$ 1.85 = 10.2 W/Gbps.

3) Influence of internal cooling power scaling and lifetime: In the beginning of this section we assumed no scaling of the internal cooling power with increased filling rates. That is, the power P_{ic} drawn by the internal cooling system was fixed, regardless of the number of slot and port cards in use, i.e. $P_{ic} = P_{icbase}$. For example, for the CRS-3 we have P_{icbase} = 619 W, see [10]. If instead we have linear scaling of the internal cooling power so that with the router fully filled it draws double the power as when empty (i.e., $P_{ic} = P_{icbase} \times (1 + f)$, with f the filling level and $0 \leq f \leq 1$), the average power rating correction factor for the CRS-3 drops from 1.77 to 1.73, which is just over 2% difference (for the T1600 we have just over 3% of difference). This strengthens our initial assumption that the impact of scaling the internal cooling power consumption can be neglected. However, note that in this case the actual power rating values will be slightly higher (because the internal cooling consumes more power); e.g., for the CRS-3 the optimal power rating then becomes 5.2 W/Gbps instead of 4.9 W/Gbps.

We also assumed an IP router lifetime of 8 years. The effect of a shorter lifetime, e.g. 3 years, depends on whether the system is either (a) left half-filled after these 3 years, or (b) instead still filled completely in 3 years (requiring a higher initial filling level, given the same annual filling rate). In scenario (a), which seems the most realistic, the average power rating correction factor will be higher than our earlier values since it operates at points with worse power ratings, see Fig. 1. On the other hand, in scenario (b), the average power rating correction factor will be lower than our earlier values, as the initial filling level will be higher, and thus operates at better power ratings. More operator data would be required for a more founded analysis. Given that scenario (a) seems to be more realistic, our earlier reported average power rating correction factors seem to be optimistic.

B. WDM Terminals

In this section we perform the same exercise for WDM terminals. A WDM terminal (de)multiplexes several WDM signals (from) into a fiber pair. A WDM terminal consists of the following functional components: a multiplexer/demultiplexer (to aggregate/de-aggregate individual channels into/from a fiber), a booster amplifier (to amplify the outgoing signal), a pre-amplifier (to amplify the incoming signal) and a number of transponders. For this study, we start with a basic chassis containing a single (de)mux, pre-amp and booster amplifier, and gradually add transponders[2] up to the maximum capacity of the system (80 channels). Overhead equipment includes the chassis with control and monitoring equipment, fans and power supply.

We used power consumption data that is based on internal measurements performed at France Telecom and product data sheets, as the data given in [3] is applicable to 10G systems and non-coherent transponders only. The results in Table III show the average power consumption of an 80-channel WDM terminal for three different data rates: 10G, 40G (coherent) and 100G (coherent). The lower power consumption of the 100G system chassis compared to the 40G system is due to vendor variation.

TABLE III
WDM TERMINAL (80-CHANNEL SYSTEM) POWER CONSUMPTION

System	10G	40G	100G
Power chassis	220 W	890 W	740 W
Power 1 transponder	44 W	167 W	389 W
Power 0% (=0 channels)	220 W	890 W	740 W
Power 50% (=40 channels)	2000 W	7550 W	16280 W
Power 100% (=80 channels)	3770 W	14210 W	31820 W

1) Power rating as a function of the filling level: In Fig. 3 we show the power rating correction factor when increasing the number of channels (i.e. transponders) installed in the terminal. The power rating (in W/Gbps) is indicated for the edge cases as well. Taking the 20% filling level as an arbitrary reference point, it is clear that the difference in power rating between an (almost) empty and a fully-filled WDM system is smaller than for IP equipment. The power rating correction factor at 20% filling level is 1.10-1.25, compared to around 2.00 for IP routers (see Fig. 1). The variation in power rating

[2]In our earlier work [3], we considered transponders *not* to be part of a WDM terminal for purposes of clarity. Here, we include them as they are critical for evaluating the filling ratio of WDM terminals.

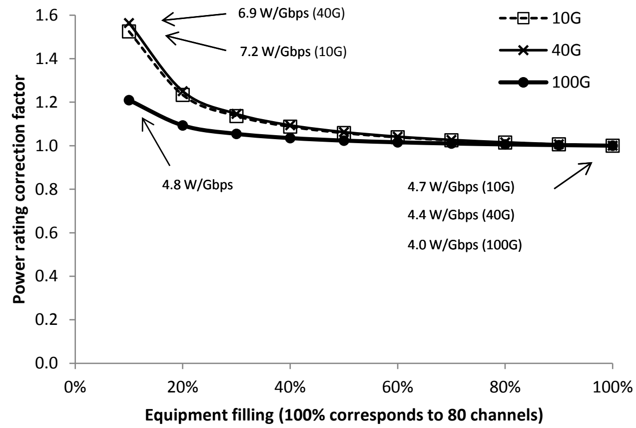


Fig. 3. WDM terminal (80-channels): power rating correction factor at increasing filling level.

correction factor of WDM terminals is less than for IP routers, because while the power rating of the functional components is about the same (i.e. for the 100G WDM transponders we have 3.9 W/Gbps, and for the IP router line cards we have 3.8 W/Gbps) the constant overhead power is smaller (740 W for the 100G WDM chassis, and 2401 W for the CRS-3 router basic node)[3]. As a result, the influence of the overhead power at low filling levels is less. In other words, if the overhead power would be (near) zero, the power rating correction factor would be 1 at all filling levels, exhibiting perfect power proportionality at system level.

2) Power rating evolution over time: Taking the same growth rate and lifetime as for IP routers earlier (i.e. doubling every two years and end-of-life at 8 years), we can plot the power rating correction factor over time. Fig. 4 shows the result for the 10G WDM terminals. The 40G and 100G results are not shown in the figure for clarity; the 40G lifetime average value is nearly identical to the 10G system (i.e. 1.21), the 100G lifetime average value is 1.08.

As could be expected from comparing the curves in Fig. 3 with those in Fig. 1, the lifetime average power rating correction factor is lower than for the IP routers.

C. Optical Line Amplifiers

OLAs are to be treated slightly differently. In [3] the resulting power values for the bidirectional OLAs were obtained for maximum-filled configurations, just as for IP equipment. That is, a shelf or rack was completely filled with OLA cards, and required overhead equipment (such as control cards and fans). This is how in [3] we came to, for example, a value of 110 W for a long span (80 km) OLA.

1) Power rating as a function of the filling level: In Fig. 5, we show the power rating correction factor of OLAs with an increasing number of bidirectional OLA cards per shelf or rack. The figure shows two different configurations from different

[3]Actually, the reasoning is slightly more complicated, as it is the ratio of the functional component's power rating *times the maximum capacity* over the overhead power that determines the sensitivity of the power rating correction factor curve.

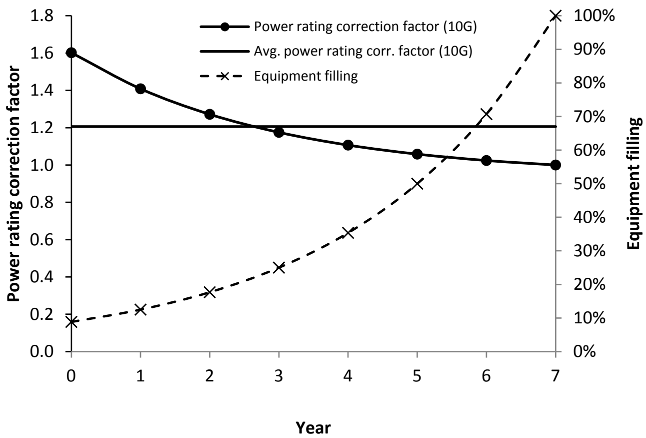


Fig. 4. WDM terminal (80-channels): power rating correction factor (left axis) and equipment filling level (right axis) evolution over time.

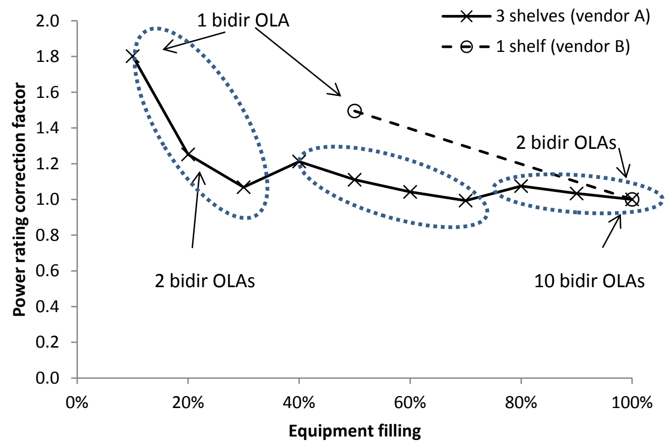


Fig. 5. OLA: power rating correction factor of a single long span bidirectional OLA as a function of the number of OLAs in the shelf or rack. The circles indicate a single shelf for the vendor A configuration.

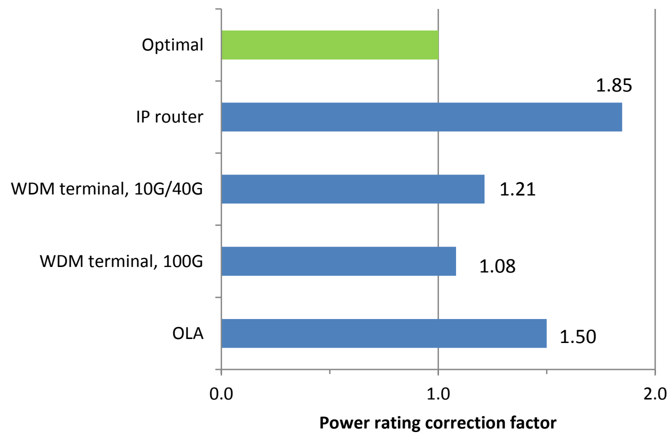


Fig. 6. Summary of the resulting average power rating correction factors as a result of increasing filling levels of equipment during its lifetime. Lifetime is fixed at 8 years, with filling doubling every 2 years (except for OLAs).

vendors. The vendor A configuration consists of a rack with three shelves, allowing a total of 10 bidirectional OLAs. The three shelves are marked with dotted elipses, and the transition can clearly be seen in the jumps in power rating correction factor. The vendor B configuration consists of only one shelf, allowing a total of only two bidirectional OLAs. As is clear from the figure, the power rating variation depends heavily on the considered architecture.

However, there is a more serious aspect to consider. For some operator backbone networks, no more than one or two bidirectional OLAs are necessary or deployed at an amplification site. This is at least the case for France Telecom's backbone, where typical links have only one, and in a few cases two, fiber pairs in use. In this scenario, the values in [3], which are mainly based on the configuration from vendor A, are overly optimistic. Based on Fig. 5, an average power rating correction factor of 1.5 on the earlier reported OLA values in [3] seems reasonable[4]. The end result is that for e.g. a long span OLA the power consumption becomes 165 W.

2) Power rating evolution over time: Above we argued that the OLAs in backbone networks (can) have low filling levels. Considering this, we can assume that the average power rating correction factor is constant over the lifetime of an OLA, and equal to the initial power rating correction factor that we determined above, i.e. 1.5.

D. Summary

The results from the previous sections are summarized in Fig. 6. The influence of the filling level over a fixed lifetime of 8 years appears to be especially relevant for IP equipment and OLAs, and less for WDM terminals. The figure shows that for IP routers a power rating correction factor of 1.85 has to be applied when considering optimal power ratings. The reason is due to the relatively high contribution of chassis power consumption to the total power. For OLAs the correction is slightly lower, i.e. 1.5, but the main reason here is that OLA equipment remains non-optimally filled during its entire lifetime. WDM terminals, finally, require a correction factor of around 1.2 for 10G and 40G equipment, and 1.1 for 100G equipment.

[4]We have averaged the individual result of the single and double bidirectional OLA configuration of both vendors, with the double bidirectional configuration weighted only half in both cases since it occurs less frequent in the field. That is: $(1.80 + 0.5 \times 1.25 + 1.5 + 0.5 \times 1.00)/3 = 1.48 \approx 1.5$.

IV. Influence of Traffic Load on Power Rating

In the previous section we have analyzed the influence of equipment filling on the power rating of core equipment. A similar exercise could be done for the influence of the traffic load. This would be relevant, as it is well-known that IP backbone traffic shows a pronounced daily variation, with off-peak traffic volume sometimes as low as 10% of the high-peak traffic, see e.g. [15].

We have only limited data available on load-dependency, but nonetheless present some of our initial findings as it indicates the relevance and might hopefully spark future work on this topic.

To evaluate traffic load, we can not use the power rating metric that we have defined earlier, as it captures the power per *capacity*. Instead we consider the existing Energy Consumption Rating (ECR) metric [16], which is defined as the power consumption (in Watt) per maximum *throughput* (in Gbps). To capture variable load, the ECR specification also defines an Energy effiCiency metRic over a Variable-Load cycle (ECR-VL), which is an average power rating over a weighted set of throughputs. If we consider the ECR value as a reference point, our power rating correction factor can then express the ratio of an ECR-VL value to the ECR value.

A. IP routers

We performed some measurements on two small core routers according to the ECR specification. The routers under test were a Cisco 7606 (160 Gbps) router and an Alcatel-Lucent 7750-SR7 (100 Gbps) router. Fig. 7(a) shows that the idle power consumption is in both cases exactly 90% of the power at full-load, linearly scaling to 100% at full load. These results confirm the earlier findings in [7] and [8]. It should be noted that the considered core routers are more than 10 years old. Newer routers might show better power proportionality. However, we did not have access to measurement data on such equipment.

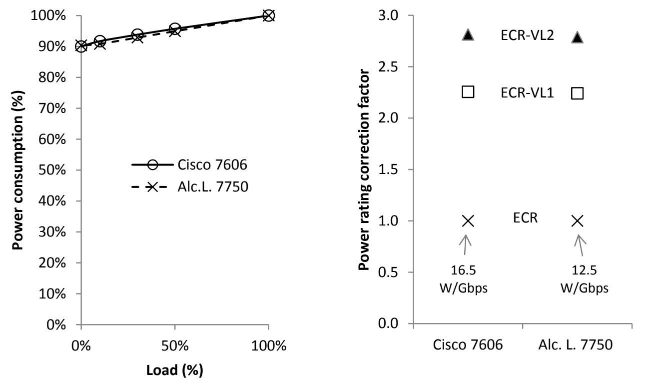
In Fig. 7(b) we show the power rating correction factor based on the outcome of two sets of our ECR-VL measurements[5]. As can be seen, the energy consumption rating under variable load is about 2.5 times the rating at maximum throughput. This implies that, given that the measured maximum throughput is nearly identical to the vendor-rated capacity[6], the actual IP router power consumption under realistic load can be estimated based on the average throughput instead of the capacity, if a factor of 2.5 is taken into account. For example, if the average load (throughput) is 30 Gbps and the capacity-based power rating of a router is 10 W/Gbps, then a realistic estimate of the power consumed would be 2.5 $\times$ 30 Gbps $\times$ 10 W/Gbps = 750 W. Without the correction factor, the power consumed would be underestimated at 300 W.

B. WDM terminals and Optical Line Amplifiers

For WDM equipment, there is to our knowledge no public data or study available on the impact of traffic load on power consumption. It seems to be accepted as a fact that the power consumption of WDM equipment varies only little with variation of IP traffic load. However, it would be nice to see this statement being backed up by actual data. Below, we do an initial exploration by looking at the influence of the number of active channels on OLA power consumption. No data is available however for IP traffic load influence, or for transponders.

[5] While the ECR specification [16] defines the relative throughput levels to take into account (100%, 50%, 30%, 10% and idle), it does not predefine the weighting factors associated with each throughput level (α, β, γ, δ and ϵ respectively). The weighting factors used in our measurements for ECR-VL1 are: α=0.1, β=0.5, γ=0.3, δ=0 and ϵ=0.1. For ECR-VL2: α=0, β=0.45, γ=0.35, δ=0.2 and ϵ=0.

[6] This was the case for the Alcatel-Lucent router, where the measured maximum throughput was 99.9 Gbps out the rated 100 Gbps. However, for the Cisco router the effectively measured maximum throughput was only 94.6 Gbps out of the rated 160 Gbps. This was due to a limitation on the router architecture, which has been solved in more recent routers of the same vendor.



(a) Measured IP router power consumption as a function of traffic load.

(b) Power rating correction factor based on two ECR-Variable Load measurements (see text for details).

Fig. 7. Power measurements for two different backbone routers.

We performed power measurements to determine how OLA power consumption is influenced by the number of active channels. The three data points on the dashed line in Fig. 8 show the power drawn by a single unidirectional amplifier for 8, 44 or 80 channels being active. When we extrapolate these results to the more practical scenario in which we consider a bidirectional amplifier (i.e., two unidirectional amplifiers) and associated shelf overhead power, we get the topmost curve in Fig. 8. The figure shows that the influence of the number of active channels on the power consumption of an OLA is minimal: for a low number of active channels, the OLA still consumes 90% of the power consumed when all channels are active.

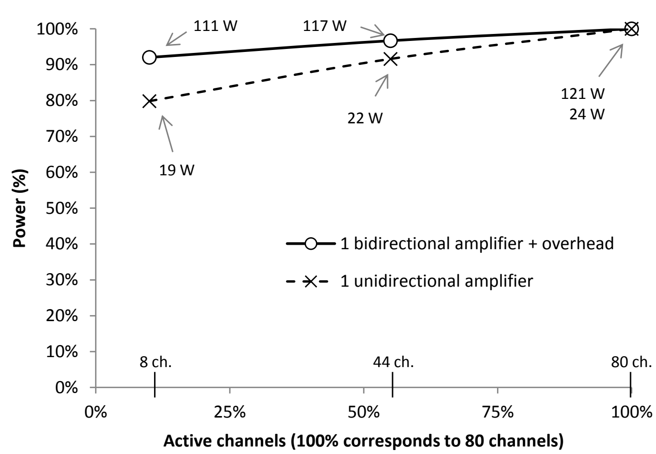


Fig. 8. OLA: power scaling with active channels

V. Conclusion

Reasonably accurate reference power consumption values are required for any work that evaluates power consumption in telecommunication networks. Many existing studies on network power consumption use optimal power rating (W/Gbps) values, meaning the power rating achieved for the maximum configuration (i.e. maximum capacity) of the system. The overhead power consumption is shared over many subcomponents, and thus contributes the least to the power rating.

In this paper, we have shown that the optimal power rating values can be almost two times too low given more realistic filling levels over the lifetime of core network equipment. Comparing IP routers, OLAs and WDM terminals, especially the former two require large corrections due to a higher overhead (for IP routers), and non-optimal filling during its lifetime (for OLAs). Detailed results can be found in Fig. 6. The impact is dependent on the actual equipment lifetime and filling rate. We have to note that if the equipment is left partially filled before the end of the assumed lifetime of 8 years, the correction factors will be even higher. As this seems to be a common practice for some operators, this would imply that our estimates are on the optimistic side.

Our power measurements on core IP routers confirms earlier findings that the idle power consumption is around 90% of the power at full-load. Power measurements on Optical Line Amplifiers with an increasing number of active channels show a similar behavior: the power consumption on lightly-loaded OLAs is again around 90% of the power consumption of OLAs with all channels active.

However, these initial results make a case for core network equipment design to become more power or energy proportional *at a system level*. The term power proportionality indicates that power consumption should scale linearly with the load, or capacity in this case. This has been discussed earlier in detail with respect to servers and computing in [17]. However, it applies equally to network equipment, not only on a component level, e.g. power consumption of slot and port cards scaling better with their load, but also on a system level when considering equipment filling levels. A perfectly power proportional network device would have an average power rating correction factor of 1. If an overall reduction of equipment power consumption is impossible at the first stage, it could be achieved by designing systems consuming more power in the incremental parts (such as slot cards, port cards and transponders) and less in the shared part (i.e. the chassis).

Useful future work would look more in depth at the influence of traffic load on the power rating values. While there is some information available for IP equipment, information on WDM components is currently insufficient for a more complete analysis.

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