# Economic benefits of an extended EPON link budget

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# Extended EPON 5 Criteria: Economic Feasibility

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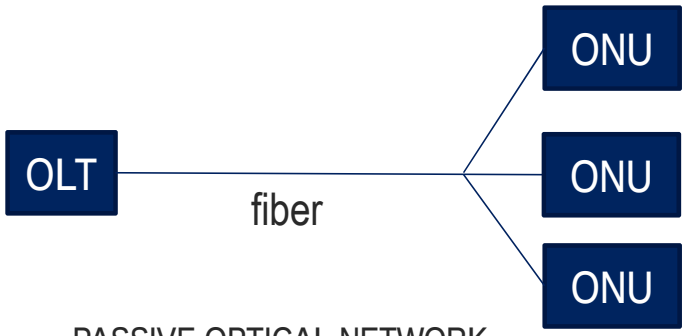
- The presentation addresses one of the *IEEE 5 Criteria Extended EPON: Economic Feasibility*

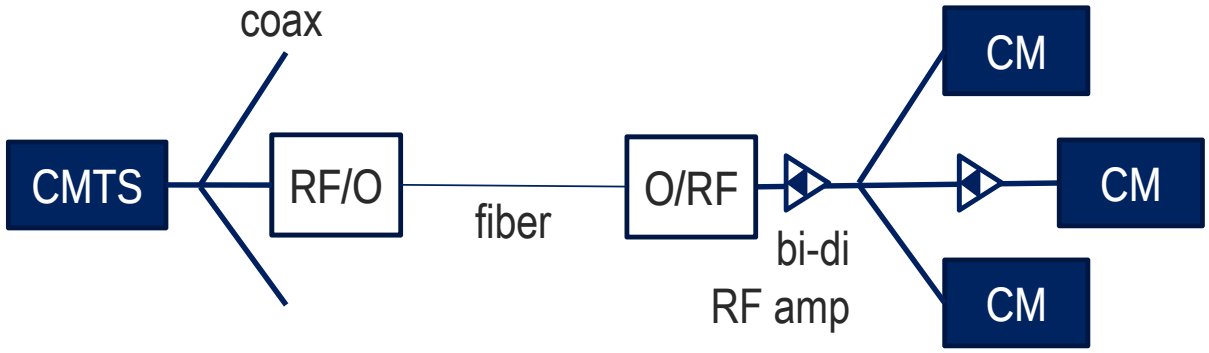
- Summary of presentation
  - Among other benefits, an *extended EPON link budget enables carriers to control OLT costs by using a pay-as-you-grow model for network deployment*.
  - *Qualitatively*, I show that *a high-split ratio* (>10,000:1) *and long reach* (> 100 km), *enabled a pay-as-you-grow deployment without which cable modem network deployments could not have been successful*.
  - *Quantitatively*, I show that the tangible *economic value of increasing the link budget supported by a single OLT optical transceiver by "6 dB" can be 2.75 × the loaded-cost of a OLT port* (representing the fully loaded OLT line-card platform divided by the number of OLT ports.)

# Lessons from cable-modem deployment

- Cable modem technology shares many features with PON technology
  - Both are point-to-multipoint access networks
    - » Broadcast downstream / TDMA upstream
    - » Shared transmission medium (coax + fiber; fiber)
    - » Tree and branch structure, with (RF/optical; optical) splitters
- But, the cable network is <u>not passive</u> between the CMTS* and CM
  - Use of hybrid fiber-coax (HFC) optical transmission and bi-directional RF amplifiers enabled > 100 km reach and > 10,000:1 split ratios for the first CM deployments in the 1990s.




PASSIVE OPTICAL NETWORK
distance / split ratio (presently limited) by
~ 30 dB optical budget:
~1:128 at 2 km
~1:64 at 10 km
~1:32 at 20 km
~1:16 at 30 km




CABLE ACCESS NETWORK
distance / split ratio can be
> 100 km / > 10,000:1

*CMTS = cable modem termination system (analog to the OLT of a PON)

# Pay-as-you-grow: the cable modem story

- For the first cable modem deployments in the mid-1990s, one CMTS might serve an entire city.
- A *>10,000:1 split-ratio* enabled the MSO to *market* CM service to *every* home in that city on day-one of deployment.
- A *>10,000:1 split-ratio* enabled the MSO *provide* CM service to the *first N customers*, who might live *anywhere* in that city.
- Only *after the first N customers* began to consume the bandwidth of the first CMTS, the *MSO installed their second CMTS*.
- The MSO's CMTS *CapEx was linked to* the *growth* of the customer base, and *revenue*.
  - Today, 15 years later, MSOs are approaching 128 homes passed per DOCSIS service group (CMTS port).
- *Cable modem economics would have failed if the initial deployments had required 128:1 split-ratios or few-km reach per CMTS port*.
- *The successful deployment of cable modems required a pay-as-you grow economic model, which required* CMTSs to support *large split-ratios and long reaches on day-one.*

# Physics rules! (the PON link budget)

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- PON link budgets, distances and split ratios are determined by optical physics, not by economics or carrier business requirements. (Higher link budgets are possible by changing the PON to an AON.)

- Questions to ponder:
  - *Is 10 Gb/s shared among 64 ONUs optimum for carrier business requirements*?
  - *Is 128:1, 256:1 or $2^{[some\ big\ number]}$:1 a more business-appropriate ONU per OLT port ratio?*

- Higher-link-budget PON would enable:
  - A lower first-deployment cost for carriers (and *pay-as-you grow* economics).
  - Centralization of central offices / headends for lower real-estate costs.

# A quantitative example – Economic benefit of an extra "6 dB" of link budget

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- By "6 dB," I mean *enough extra link budget to increase the PON split-ratio by a factor of four* over what is possible today with an "existing PMD"
  - » In reality "6 dB" is probably > 7 dB.
- I assume this extra link budget is achieved entirely by the use of an OLT optical transceiver with higher optical output power and better receiver sensitivity. (No changes at the ONU.)
- Using standard accounting tools, *I calculate the savings* (present value) that a carrier will realize *over an 8-year network deployment* by deploying OLT ports on a *pay-as-you-grow model vs. deploying all OLT ports on day-one*.
- *This example under-estimates the total economic value*, since it does not include *intangible economic benefits of a pay-as-you-grow model*, such as de-risking the carrier from potential future negatives such as
  - Low than expected customer up-take
  - Technology risk (*e.g.* Many WiMAX network operators now wished they had deployed LTE)
  - Rapidly changing economic conditions

# Accounting 101 – Net present cost, time-value of money, discount rate

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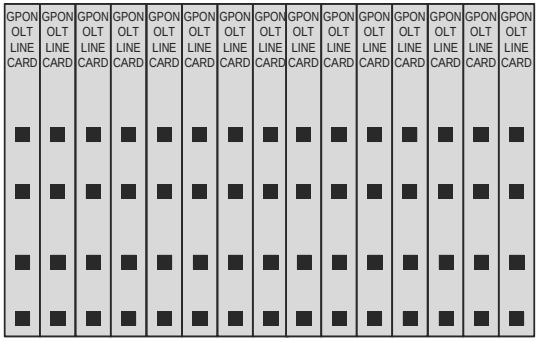
- In this example, I calculate the OLT line-card costs over an 8-year network deployment.
- I use the concept of *net present cost*, which is a way of accounting for the *time-value of money*.
  - » This is a standard accounting tool used by public and private companies, component makers, network equipment suppliers, carriers, and governments.
  - » To an engineer or scientist this may seem artificial, abstract, and ad-hoc. To business decision makers, however, the *time-value of money* is as real as the electric charge of an electron.
- *Basic idea:* There is an economic value to being able to pay for something one-year-from today instead of today.
- Accountants account for this value by assigning future money a *discount rate*.
  - » Example: if I think the value of having 100 coins in my pocket one-year from today is worth 90 coins today, I have assigned a *discount rate* of 10% / year to the *time-value of money*.
  - » The *discount rate* is based not only on the interest one could earn on the money in a bank account, but also on the rate of inflation / deflation, expected returns in the stock markets, *etc*. *Most importantly for businesses,* however, *it represents the opportunity cost of not being able to do something else* (with an expected positive return on investment).
- It is my understanding that *most carriers utilize a 10–15% / year discount rate* in assigning net present values, costs and savings to planned projects.

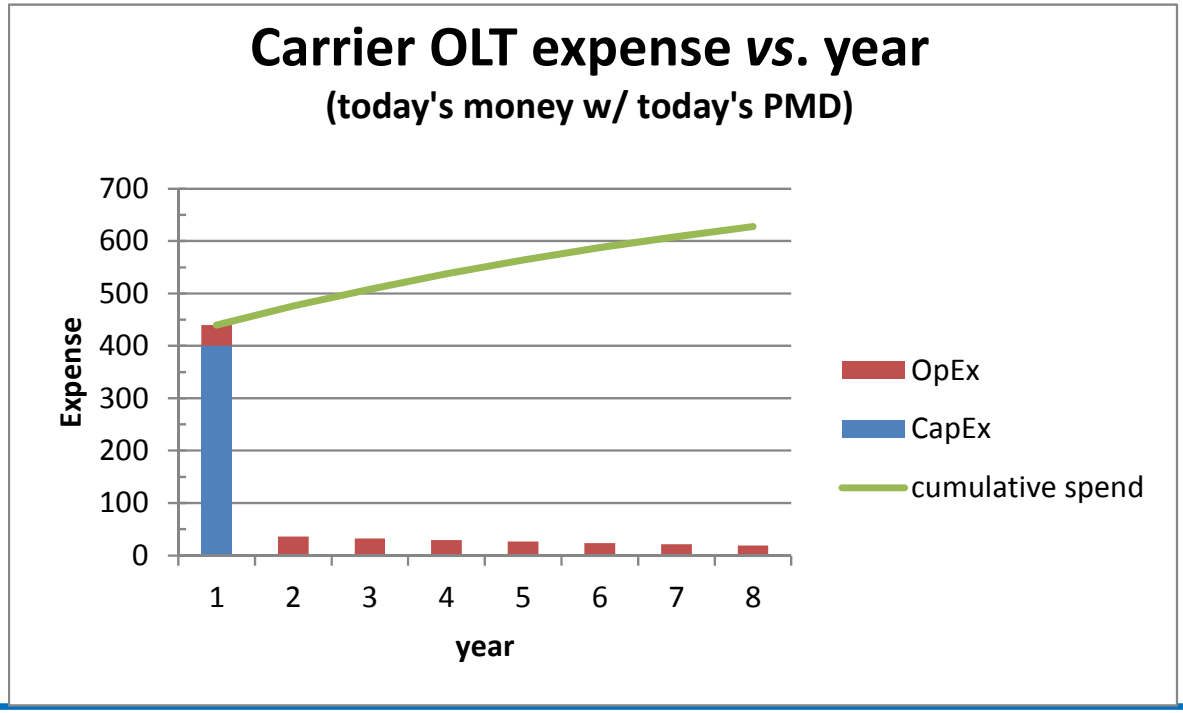
# Cost assumptions in the example




- Following IEEE rules, I assign *relative costs only*.
- I assume that (the cost of PON OLT platform, fully-loaded with PON OLT line-cards, power supplies, up-link line-cards, and *all* optical transceivers) ÷ (number of PON ports) ≡ *cost per OLT port = 100.*
- I assume that OpEx costs (electrical power, real-estate, technical support, management, *etc*.) are 10% of initial CapEx cost per year.
  - Planned *yearly OLT OpEx = 10 / per OLT port*. (I understand that 10% is a reasonable rate for carriers – any input from carriers would be appreciated.)
- I assume that the *cost for networking equipment drops at a rate of 10% / year.*
- I assume a *discount rate of 10% / year.*

# Scenario 1 – base case

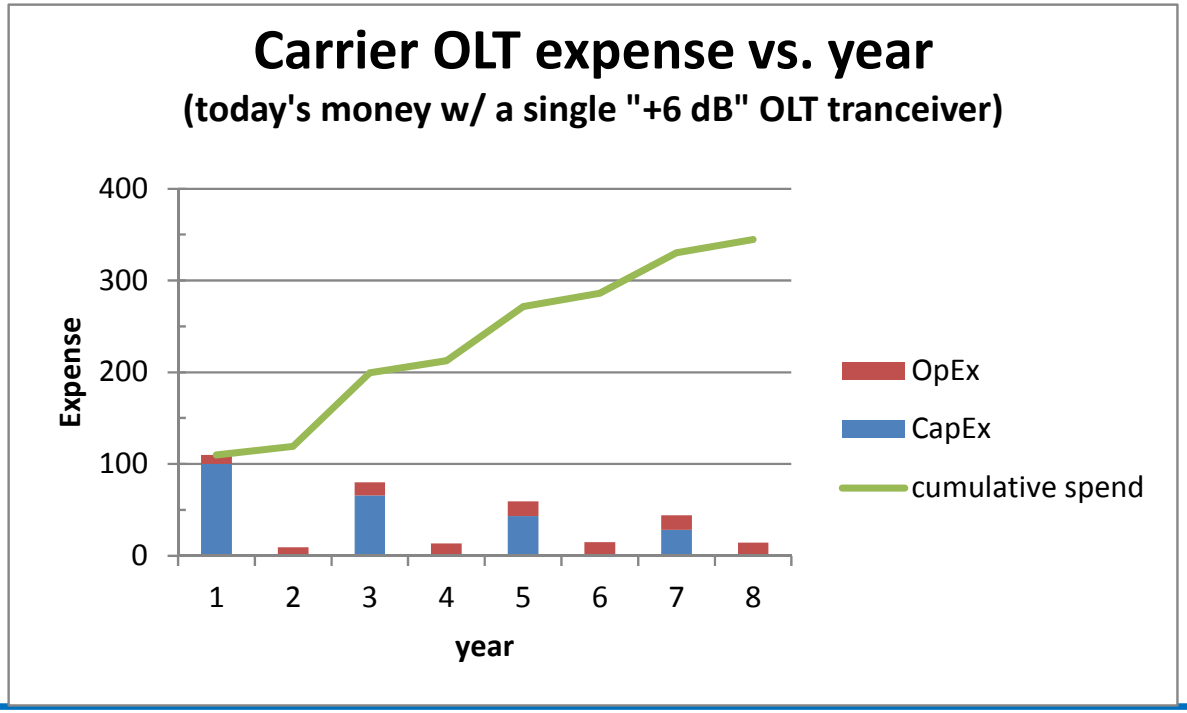
- In the first scenario, four OLT ports are deployed on day-one. All CapEx spending (400) happens in year-one, and the OpEx spending is 40 per year for the life of the project. A discount rate of 10% / year is applied to relate future spending to today's money.




Net present OLT cost for 8-year deployment is 628

# Scenario 2 – pay-as-you-grow

- In the second scenario, a single OLT port is deployed on day-one. Its transceiver enables an additional "6 dB" of link budget and supports the same-split ratio as four standard PMD OLT transceivers. As bandwidth demand and/or customer penetration increases, new OLT ports (with today's standard-PMD transceivers) are added over the 8-year project*.
  - First install CapEx is 100, and further CapEx per OLT port falls due to a real 10%/year drop in equipment prices and application of the 10%/year discount rate. Similarly Net OpEx cost is reduced.




Net present OLT cost for 8-year deployment is 345

* As new ports are added, the now under-utilized link budget of the original port can be used as live equipment redundancy support for the added OLT ports.

# Summary

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- The experience of the cable industry shows that supporting *a high link-budget on day-one is essential to enable pay-as-you-grow economics for network deployment.*

- A qualitative example is given in which *a single OLT optical transceiver supporting "6 dB" of extra link budget* (compared to "today's PMD") *enables a pay-as-you grow economics* for a carrier's (loaded) OLT costs.
  - In the example, this single extended OLT optical transceiver *lowers the carrier's first-install OLT cost by a factor of four*. (400 → 100)
  - In the example, the carrier's net present (loaded) *OLT cost in the pay-as-you-grow deployment is 54% of* net present (loaded) *OLT cost of the deployment with "today's PMD" only.*
  - In the example, *the value generated by boosting the link budget of a single OLT optical transceiver by "6 dB"* (628 – 345 = 283) *is 2.8 × the (loaded) cost of a single OLT port* (=100, representing cost of a fully-loaded OLT line-card platform divided by the number of OLT ports.)