IEEE802.3at Task Force

Enhanced Classification
Economical and Technical Worst case Analysis

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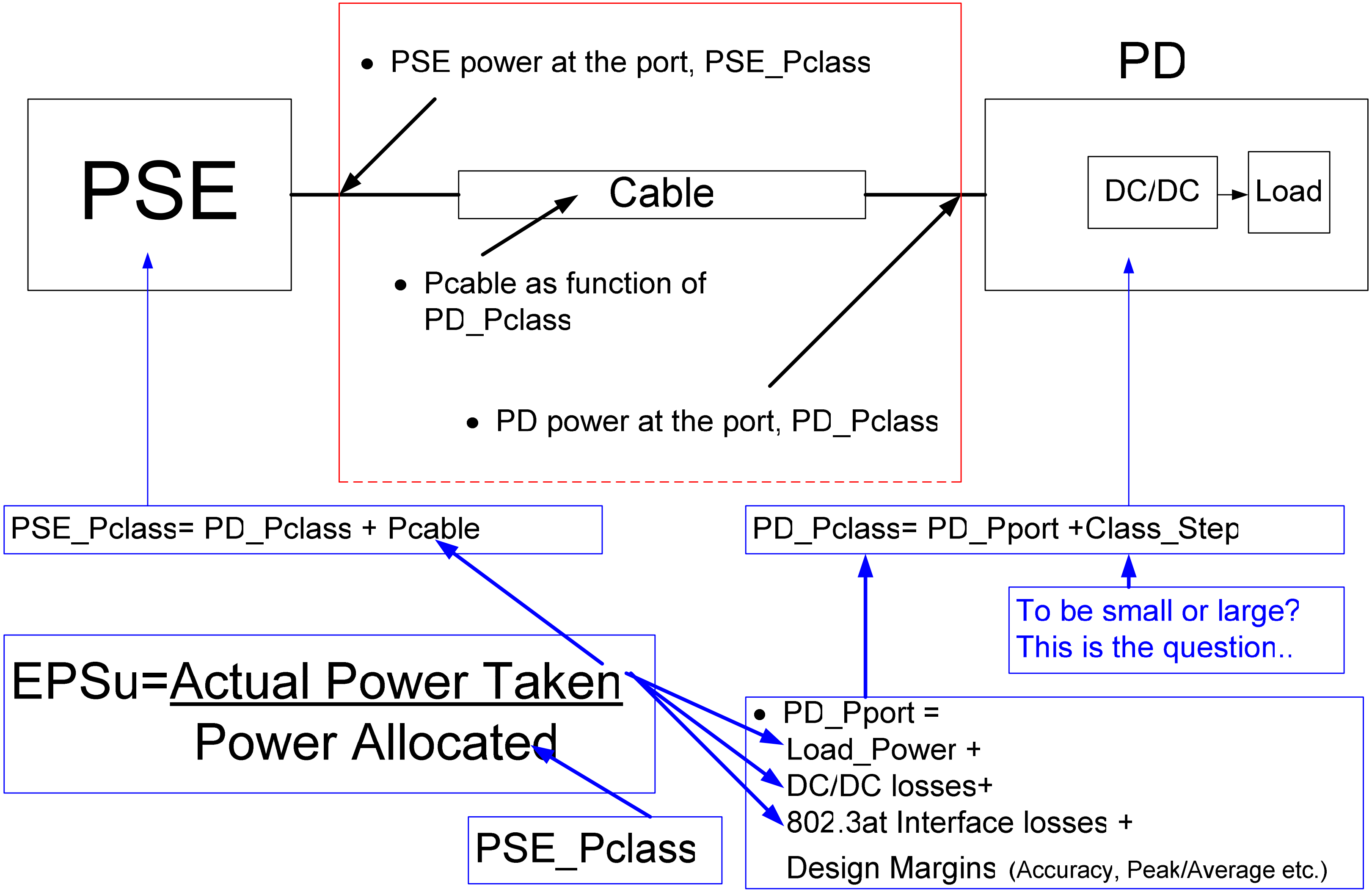
Objectives

- Part 1
- To suggest a simple tool for calculating the minimum number of classification required based on worst case analysis
- To find the break even point where power supply savings in $/W is equal to the cost of testing N classifications

- Part 2
- Recommendation for the 802.3at group based on practical considerations

Power Supply Utilization, PSu Definition

PSE <u>Effective</u> Power Supply Utilization Definition



802.3at Layer 1 Scope - PD side

- At the PD port: Pclass = Pport + Class_Step

PD vendor controls:
•Load_Power +
•DC/DC losses +
•802.3at Interface losses +
•Design Margins
  -Design Accuracy
  -*Peak and Average behavior etc which can be optionally transferred to PSE via Layer 2 or equivalent with improved granularity and dynamic behavior*

(PD vendor controls → Pport)

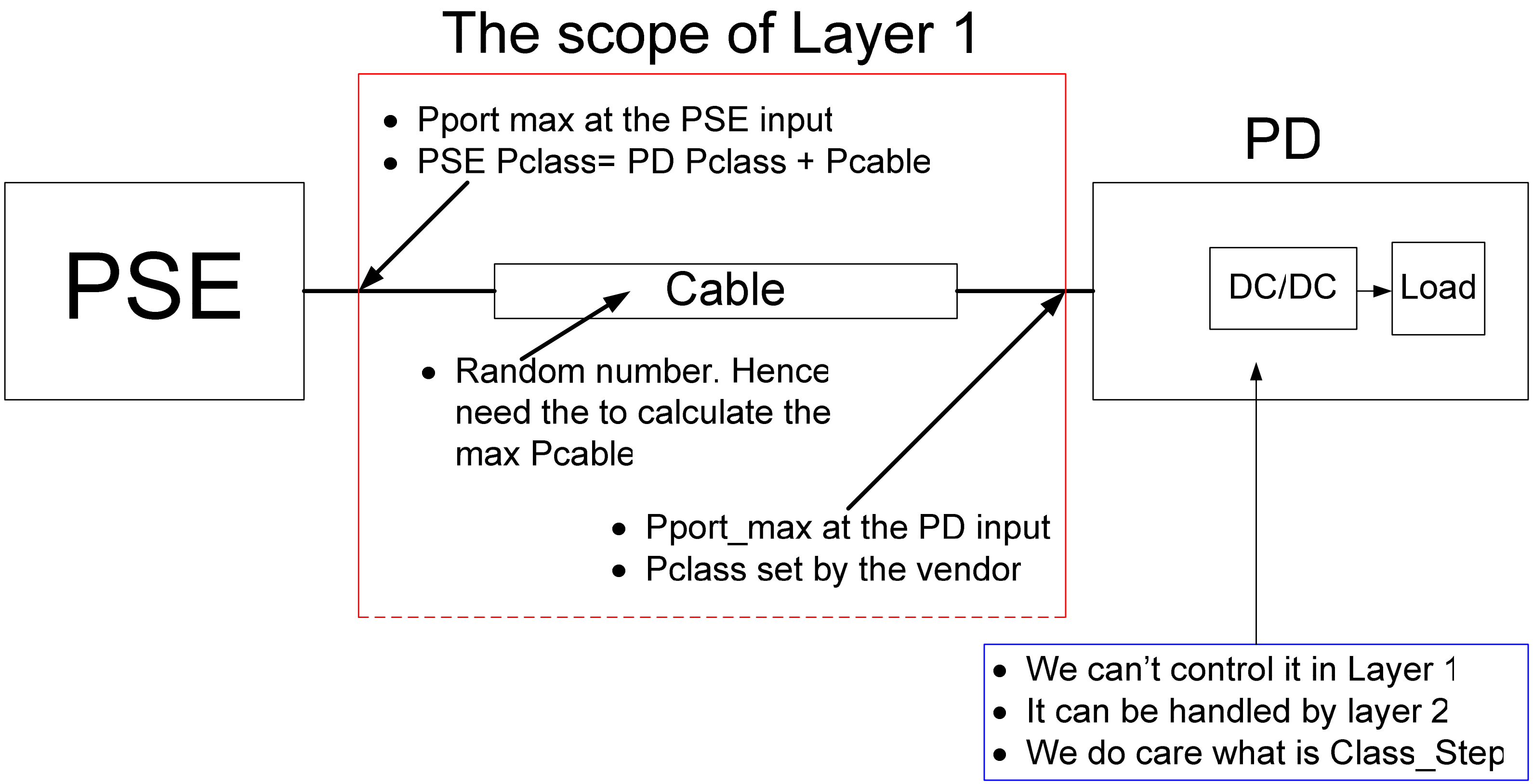
802.3at Standard Controls:
Class Step ➔ Number of Class Steps in Layer 1

(802.3at Standard Controls → Class_Step)

802.3at Layer 1 Scope - PSE side

- We need to specify what system vendors consider as Sufficient Power Supply Utilization factor based on:
  - PSE PS Cost.
  - Power Management system margins.
  - Number of ports.
  - Mission Critical or not
  - Addressable Market statistics
  - And More..
- It means that PSu can be never 100%
- Especially if that PD load is never the actual load

802.3at Layer 1 Scope - Summary

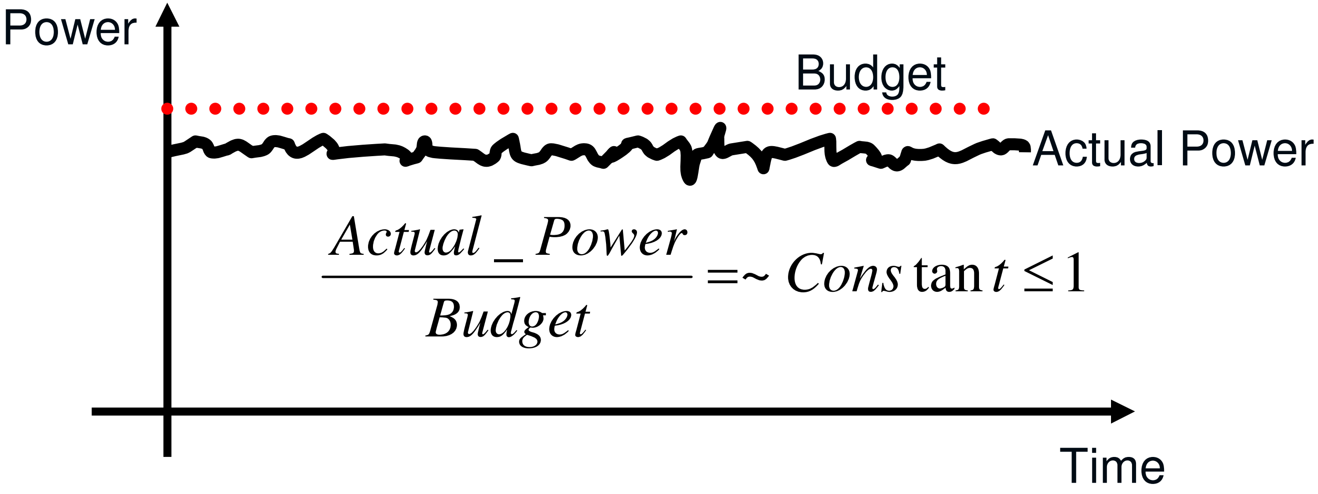


$$PSu = \frac{\text{Actual Power Taken}}{\text{Power Allocated}} = \frac{PD\_Pport + Pcable}{PD\_Pport + Class\_Step + Pcable}$$

EPSu < PSu due to loses that can't be controlled by the standard, part of it can be controlled by layer 2

Ideal Power Management

- To have maximum utilization of the power sources
- All the time



$$\frac{Actual\_Power}{Budget} =\sim Constant \leq 1$$

Worst case analysis of # of classes

- PSu=Actual Power Taken / Allocated Power (1)
- Actual Power Taken = PD_Pport_max + Pcable_max (2)
- Analysis method: Worst case
- Meets PSu for
  - Any and every port in a multi-port system
  - The limiting factor is available power and not "out of ports" to power situation.
- Hence we need to maintain at the PSE for every port in the system.
- PSu= Pport / Pclass = Constant. (3)
- Or 1/PSu= Pclass / Pport (4)
- Generating a table from Pclass_minimum to Pclass_maximum that each consecutive value of Pclass is higher by factor of 1/PSu=constant.

Worst case analysis of # of classes Cont.

- Example (Testing the case of 2W to 100W range):
- Find the minimum number of classes to cover the range from Class_min=2W to Class_max=100W at the PD side.
- Assuming PSu target =90%=0.9 ➔ 1/PSu=1/0.9=1.111
- Pclass1=2W
- Pclass2=2W *1.11
- Pclass3=2W *1.111*1.111 = 2W *1.111^2
- Pclass4=2W *1.111*1.111*1.111 = 2W *1.111^3
- .
- .
- PclassN=2W *1.111^(N-1) = 100W

- N = 1 + log(Pclass_max/Pclass_min)/log (1/PSu)
- N= = 1+ log(100/2)/log(1/0.9)=38-39 classes

of Classifications vs PSu

			Psu	
Psu	0.7	0.8	0.9	0.95
1/Psu	1.429	1.25	1.111	1.053
N	12	19	39	78

Number of classes are significantly increased at higher PSu and power range

Number of classes N, for 100W over 2P. Total 100W/port

			Psu	
Psu	0.7	0.8	0.9	0.95
1/Psu	1.429	1.25	1.111	1.053
N	11	16	32	64

Number of classes N, for 50W over 2P, 100W over 4P

Important notes

- At this point for the sake of simplicity:
- Uniform PD distribution (in reality it is not true and correction factor will be supplied later)
- Effects of Power Measurement accuracies are neglected and will be manually corrected in the next example.
  - Can be done analytically as well
- Effects of “There are no PDs that requires < Pmin” are addressed manually in the next example.
  - Can be done analytically as well

Example: Logarithmic Power Distribution as function of PSu and number of classes for uniform PD load distribution for 2 to 100W range

Psu	0.7	0.8	0.9
1/Psu	1.42857	1.25	1.11111
N	11	16	32
1.00	2.00	2.00	2.00
2.00	2.86	2.50	2.22
3.00	4.08	3.13	2.47
4.00	5.83	3.91	2.74
5.00	8.33	4.88	3.05
6.00	11.90	6.10	3.39
7.00	17.00	7.63	3.80
8.00	24.29	9.54	4.22
9.00	34.69	11.92	4.65
10.00	49.56	14.90	5.16
11.00	70.80	18.63	5.74
12.00	101.15	23.28	6.49
13.00		29.10	7.21
14.00		36.38	7.87
15.00		45.47	8.74
16.00		56.84	9.71
17.00		71.05	10.79
18.00		88.82	12.95
19.00		111.02	13.32
20.00			14.81
21.00			16.45
22.00			18.28
23.00			20.31
24.00			22.57
25.00			25.07
26.00			27.86
27.00			30.95
28.00			34.39
29.00			38.22

Un used power between consecutive high classes in uniform PD distribution

Psu	0.7	0.8	0.9
30.00			42.46
31.00			47.18
32.00			52.42
33.00			58.25
34.00			64.72
35.00			71.91
36.00			79.90
37.00			88.78
38.00			98.64
39.00			

Analyzing the example results

- Guarantees constant worst case PSu for every port in the system for uniform PD distribution. (Which is not the real case and will be adjusted later in next slide)
- Each consecutive class is higher by 1/PSu
- Actually fits to logarithmic distribution of the power range between classes

- Disadvantages:
- If PDs are not uniformly distributed then we may lose a lot of power at the high classes
- The solution:
- To use logarithmic distribution of the power over classes in the lower classes
- Close to linear distribution in higher classes.

Example: Where is the border line between Log and Lin distribution?

Psu	0.7	0.8	0.9
1/Psu	1.42857	1.25	1.11111
N	11	16	32
1.00	2.00	2.00	2.00
2.00	2.86	2.50	2.22
3.00	4.08	3.13	2.47
4.00	5.83	3.91	2.74
5.00	8.33	4.88	3.05
6.00	11.90	6.10	3.39
7.00	17.00	7.63	3.80
8.00	24.29	9.54	4.22
9.00	34.69	11.92	4.65
10.00	49.56	14.90	5.16
11.00	70.80	18.63	5.74
12.00	101.15	23.28	6.49
13.00		29.10	7.21
14.00		36.38	7.87
15.00		45.47	8.74
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19.00		111.02	13.32
20.00			14.81
21.00			16.45
22.00			18.28
23.00			20.31
24.00			22.57
25.00			25.07
26.00			27.86
27.00			30.95
28.00			34.39
29.00			38.22

Logarithmic / Linear border is here:

Psu	0.7	0.8	0.9
30.00			42.46
31.00			47.18
32.00			52.42
33.00			58.25
34.00			64.72
35.00			71.91
36.00			79.90
37.00			88.78
38.00			98.64
39.00			

- It is the point where:
  Pclass(n)/Pclass(n-1)>Pclass_min.
- Pclass_min is the lower power PD that we wish to support!

Analytical Solutions to address all the assumptions

- Simplified
- Pmax=Pmin*(1/PSu)^(n-1) ➔
- N=1+LOG(Pmax/Pmin)/LOG(1/PSu)
- Realistic:
- Pmax=Pmin*(1/PSu)^(Effective N -1)
- Effective N = N-K1-K2+K3
- K1 All classes that Pclass(n+1)/Pclass(n)<Power Measurement Accuracy
- K2 all the classes that exhibits Pclass(n+1)/ Pclass(n)<Pmin
- K3 all the classes that exhibits Pclass(n+1)/ Pclass(n)>Pmin
- Next level in improvement should be done in layer 2 or equivalent algorithms to account for Pmax/Pavg ratio data

Summary of Part A – Calculating # of classes

- Tool for Calculating Minimum Number of classes, N has been presented for uniform PD distribution that allows ~constant PSu
- Trimming the real non uniform PD distribution can be done easily by using log scale until the border point and close to linear scale above it
- The border point is when Pclass(n)/Pclass(n-1)>Pport_min

1. N = 1 + log(Pclass_max/Pclass_min)/log (1/PSu)
2. Pmin to Px ➔ Logarithmic scale
3. Py to Pmax ➔ Close to linear scale
4. Py is the class that is > Px by Pmin

Economical Analysis of Enhanced Classification as function of the number of classes.

Assumptions

- The group did a good job and selected relatively non complex concept.
- There are not many or non “illegal” codes that may affect the testing time and cost in the chip and system level.
- The cost is a worst case function of the number of classes hence linear dependence.
  - In reality it is less then the number of classes in a multi-port system hence it is real worst case assumption.

Break even point: power supply savings in $/W is equal to the cost of testing N classes Cont.

- 802.3at Classification testing cost =C
- C=N* Class_$=
- N= [1+log(Pmax/Pmin)/log(1/PSu)]
- C=N* Class_$

- Un used power=Plost.
- Plost= (1-PSu)*Pmax
- Cost of Plost = Pmax*(1-PSu)* Power_$/W

- <u>Break even point for PSu</u>

Plost*Cost of power/W = Test_cost*Number of classes

- Pmax*(1-PSu)* *Power_$/W* = *Class_$* *[1+log(Pmax/Pmin)/log(1/PSu)]

Break even point: power supply savings in $/W is equal to the cost of testing N classes Cont.

- Pmax*(1-PSu)* Power_$/W / Class_$ = 1+log(Pmax/Pmin)/log(1/PSu)
- Pmax*(1-PSu)* 23.58 = log(Pmax/Pmin)/log(1/PSu)

  and using Excel Goal Seek function..for Pmax=100W, Pmin=2W

- 23.58 is Vendor A data with some margins.
- Class_$ is varying from vendor to vendor.
- Lets assumes that other vendors pay more for testing by factor of 2

- Hence Break even point is;
- for Power_$/W / Class_$ =23.58, B.E is at PSu=0.96 → N=96
- for Power_$/W / Class_$ =11.79, B.E is at PSu=0.943 →N=68

- Above these numbers we pay on testing more then we save on power…
- So using N<<68 makes the cost of classification testing not an issue.

Summary of economical analysis of N

- In Layer 1:
- If Number of Classes <<68-96
  - ➔Power loss cost >> Classification testing cost
  - ➔Then Testing cost is not an issue

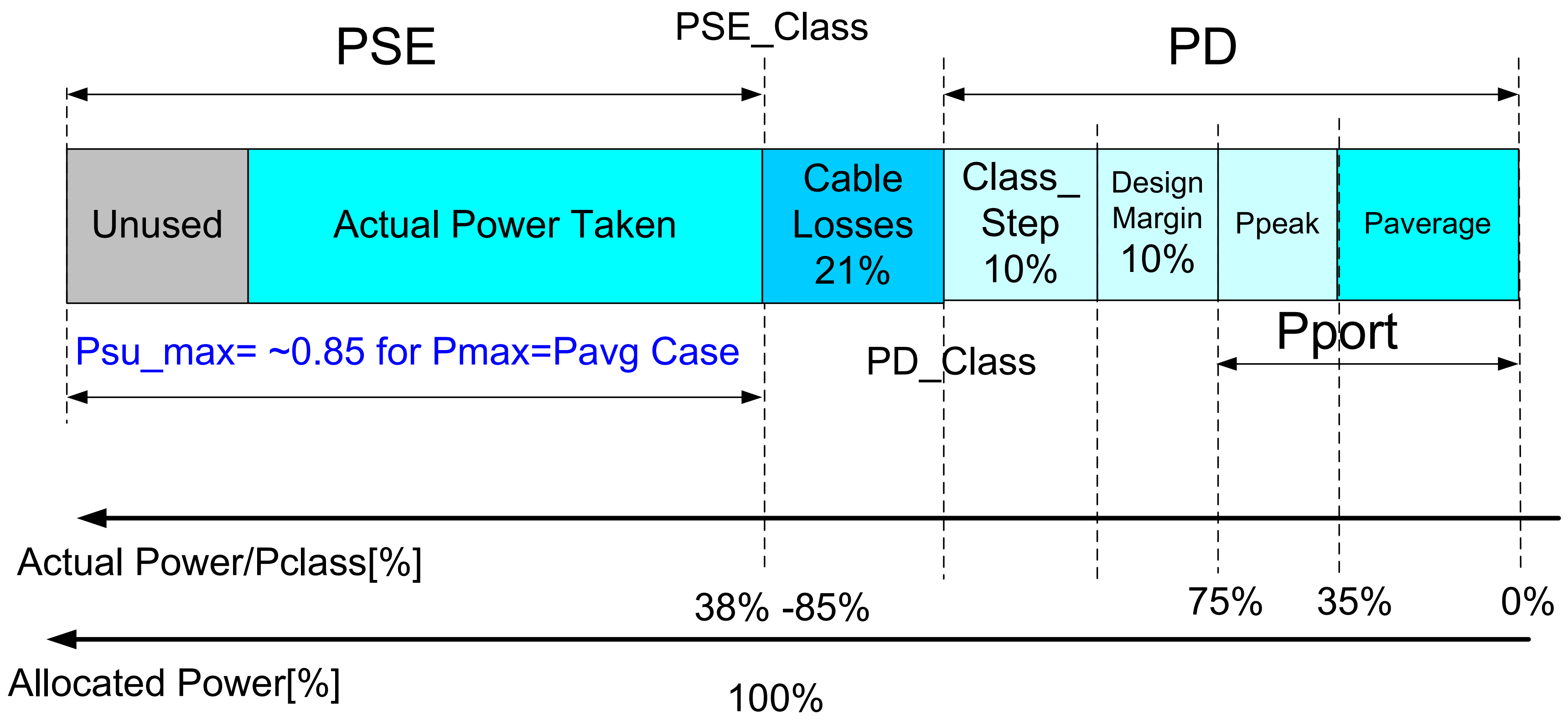
Recommendation for the 802.3at group based on practical considerations

Sanity Check for practical SYSTEM limitation

Ppd	PD max power [W]	20	25	27	30	35
dm	Design Margin	10%	10%	10%	10%	10%
Ppd_1=Ppd*(1+dm)	PD input power max	22	27.5	29.7	33	38.5
Cstep	PD Class_step	10%	10%	10%	10%	10%
Pdclass=Ppd1*(1+Cstep)	PD Class max	24.2	30.25	32.67	36.3	42.35
	Vpse	51	51	51	51	51
=(Vpse-(Vpse^2-4*12.5*Ppd)^0.5)/25	Ipse max	**0.440**	**0.570**	**0.625**	**0.713**	**0.873**
=Ipse^2*12.5	Pcable_max	2.415	4.058	4.886	6.35	9.529
=Pdlass+Pcable	PSE Class max	26.61	34.31	37.56	42.7	51.88
=Pcable+Ppd	Pport PSE ACTUAL max	22.41	29.06	31.89	36.4	44.53
=Pport PSE Actual/PSE Class	Psu_maximum	0.842	0.847	0.849	0.85	0.858

- Marginal Max current per wire limitation according to TIA document

PSu max for 20 to 35W PD load



So

- PD max power over 2P ➔ 30W
- Meets minimum power requirements ➔OK
- Max power over 4P can be 60W max ➔ OK
- Max achievable PSu in Layer 1 is 0.85.
- Actual PSu is more depend on Ppeak/Paverage ratio
- Hence Pmax for calculating N is 30W.
- Classes from 30W to 100W should be reserved for future use

Of classes as function of Ppeak/Paverage

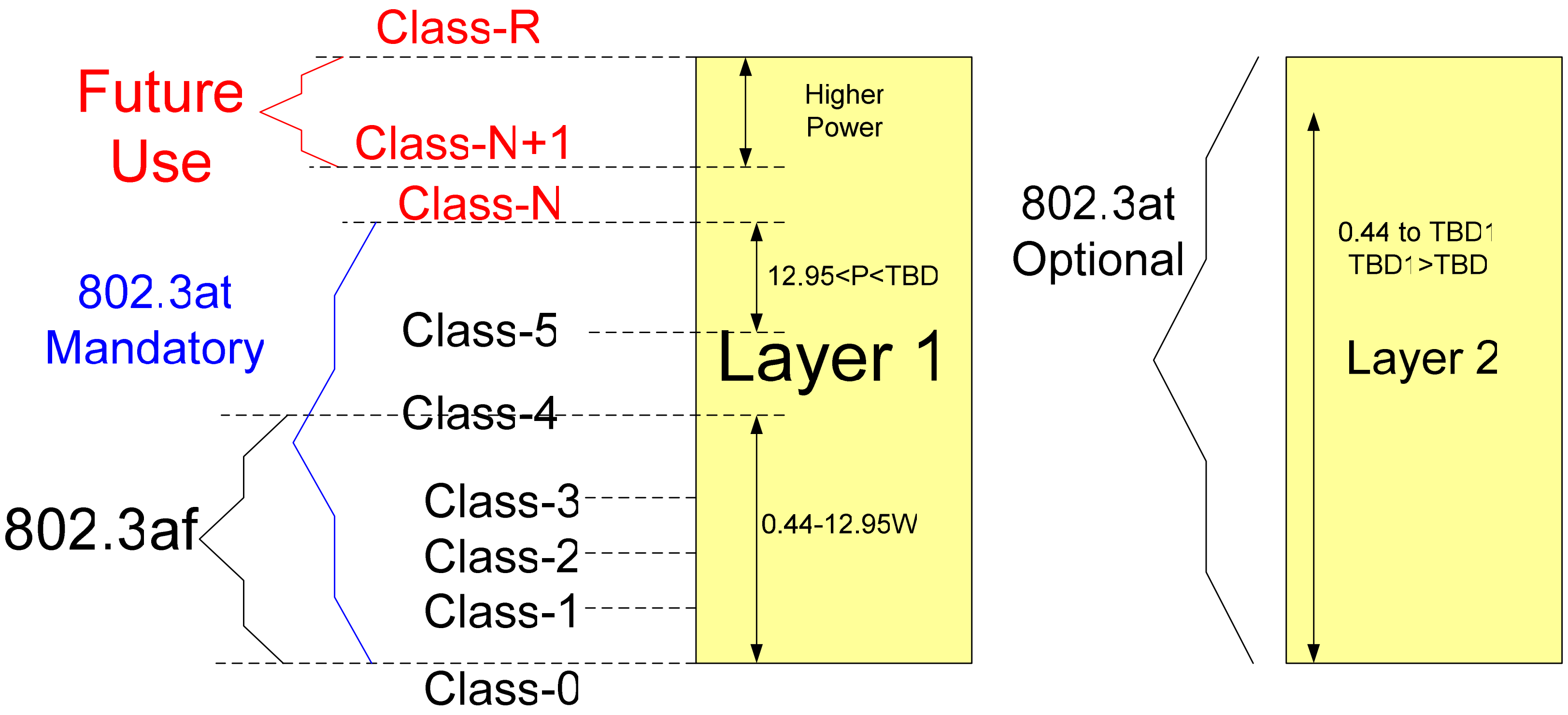
Psu	N	Ppeak/Pavg
0.85	18	1
0.76	11	1.1
0.68	9	1.2

<u>Number of classes required for 30W</u>

- PSu=85%: N=1+LOG(30/2)/LOG(1/0.85)=18
- N=18 << N=68 – 96 hence cost effective!
- PSu=68% N=11-12

802.3at Classification proposal

Handling:
- Ppeak
- Paverage
- Management



Summary

- Max PSu for Pmax=30W is ~0.85 for Ppeak=Pavg
- Pmax=30W is practical assumed to be max power today
- N=11-18 for 30W max over 2P for Layer 1.
- N>18 is required if 2*30W on 2P alone.
  - Therefore it is Recommended to use 4P Architecture that use two 2P power channel each addressed by detection and classification phase. (In addition helps to solve other system issues)
- To reserve additional 20 classes for future use for supporting up to 50W/2P for future use