IEEE802.3poep Study Group

Class Resolution Requirements Analysis

Based on detailed analysis attached to this presentation

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Yair Darshan/ PowerDsine

Objectives

- To optimize power management performance based on the PD classification method by optimizing PSE power supply utilization
- Set the rules for:
  - Classification Resolution
  - Number of classes
- Understanding the practical limitations and their origin
- Suggesting design procedure
- Mapping the missing information for getting intelligent decision

Classification based power management

- Principles
- Prior to the power up of the PD, PD Classification is the only available data for power allocation. See Annex A
- The classification information from the PD represents the max power required by the PD.
- The PSE power supply has a power budget that is decreased by the last PD class detected, Pclass.
- The actual power taken by the PSE is Pport.
- The unused PSE PS power $\sum_{i=1}^{N}(Pclass - Pport)_i$ costs us with
  - less available power to the ports
  - Lower on time
  - Higher PSE power supply costs
- The objective is to optimize the power supply utilization factor, PSu.

The analyzed model

- The PSE has:
  - a power budget, Pbudget
  - N ports, each port supports Pport which is a random variable.
    - The random variable is described by a probability function.
    - Probability function is a function that assigns to each value of Pport, the probability that it will happen.
- In a known environment, each port has the same probability function.
- The minimum power class resolution is Class_step
- Class step may be linear or non linear.
  - In the following analysis the linear case is discussed first in order to set the foundation for further analysis.
- The objective is to optimize the PSu.

Analysis method

- Using the averaging concept in order to simplify the math required

- Detailed analysis attached in a separate document.

Analysis Summary.

- PSE power supply utilization factor is defined as:
- Eq-1

$$PSu = \frac{Actual\_Power\_Taken}{Pbudget}$$

- Eq-2

$$Actual\_Power\_Taken = \sum_{i=1}^{N} Pport_i$$

Pport is a random variable

- Eq-3.1

$$avg(Actual\_Power\_Taken) = avg\left(\sum_{i=1}^{N} Pport_i\right)$$

- Eq-4

$$Actual\_Power\_Taken\_avg = \sum_{i=1}^{N} Pport\_avg_i$$

Analysis Summary..

- Eq-5 $$Pport\_avg_i = \sum_{j=1}^{m} Pport_j \cdot p_{i\,j} = \sum_{j=1}^{m} Pport_j \cdot f_{ij}(Pport)$$

- Eq-4+Eq-5 results with Eq-6: the general case of the actual average power taken from all PSE ports and with any probability function for each port.

- Eq-6 $$Actual\_Power\_Taken\_avg = \sum_{i=1}^{N} \sum_{j=1}^{m} Pload_j \cdot f_{ij}(Pload)$$

The average for all the ports

The average per port

Probability function example

j	$p_{j=} f_{ij}(Pport_j)$	$Pport_j$
1	0.3	5W
2	0.25	7W
3	0.15	11W
4	0.15	20W
5	0.13	25W
6	0.02	56W
	$\sum_{j=1}^{m} p_j = 1$	$Pport\_avg_i = \sum_{j=1}^{m} Pport_j \cdot f_{ij}(Pport) = 12.27W$

Analysis Summary..

- The probability function is mainly a function of :
  - The market being addressed
  - Target organization and usage
  - Vendor considerations (cost vs performance)
- In this case the probability function can be anything (random variable too)
- In order to bypass this problem we will use the fact that in a known environment, each port has the same probability function, hence it generates the same average power per port for any port in the box.

$$Actual\_Power\_Taken\_avg = \sum_{i=1}^{N} \sum_{j=1}^{m} Pload_j \cdot f_{ij}(Pload) \qquad \textbf{Eq-6}$$

- Therefore Eq-6 is reduced to the form of Eq-8

$$Actual\_Power\_Taken\_avg = \sum_{i=1}^{N} Pport\_avg_i = N \cdot Pport\_avg_i$$

$$Actual\_Power\_Taken\_avg = N \cdot Pport\_avg \qquad \textbf{Eq-8}$$

Analysis Summary..

- Eq-8 supplies the data which is required for the actual average power taken.

$$Actual\_Power\_Taken\_avg = N \cdot Pport\_avg \qquad \textbf{Eq-8}$$

- Hence the budget, Pbudget, should be set to at least the same value in order to supply the demand.

- According to the working model, the system reads the class information from the PD therefore the budget, Pbudget should be set to support the average class value as known to the PSE.

Analysis Summary..

- The PD defines its class according to the actual maximum power that it needs and the minimum class step possible according to Eq-9.
- Eq-9: How the class is set in the PD

$$Pclass_i = \left(ceil\left(\frac{Pport_i}{Class\_step} \right) \right) \cdot Class\_step$$

- Where:
- -Pclass is the class information in watts that describes Pport.
- -Class step is the class resolution i.e. minimum difference between two consecutive classes.
- -Ceil is a function that rounds up the number to the next integer.
- Example: If Port=4.5W and the minimum class step (Class resolution) is 2W than the actual class is 6W. (ceil(4.5/2))*2=6.

Analysis Summary..

- Averaging Eq-9
- Eq-10 $$Pclass\_avg_i = \sum_{j=1}^{m} Pclass_j \cdot f_{ij}(Pport)$$
- Eq-11 $$Class\_avg_i = \left(ceil\left(\frac{Pport\_avg_i}{Class\_step} \right) \right) \cdot Class\_step$$
- Therefore, Pbudget value to supply the demand (Actual_Power_Taken_avg) is:
- Eq-12 $$\text{Pbudget} = Class\_avg_i \cdot N = Class\_avg \cdot N$$

Analysis Summary..

- Therefore PSu average (our objective..) is

$$PSu\_avg = \frac{Actual\_Power\_Taken\_avg}{Pbudget} = \frac{Pport\_avg \cdot N}{Class\_avg \cdot N} = \frac{Pport\_avg}{Class\_avg}$$

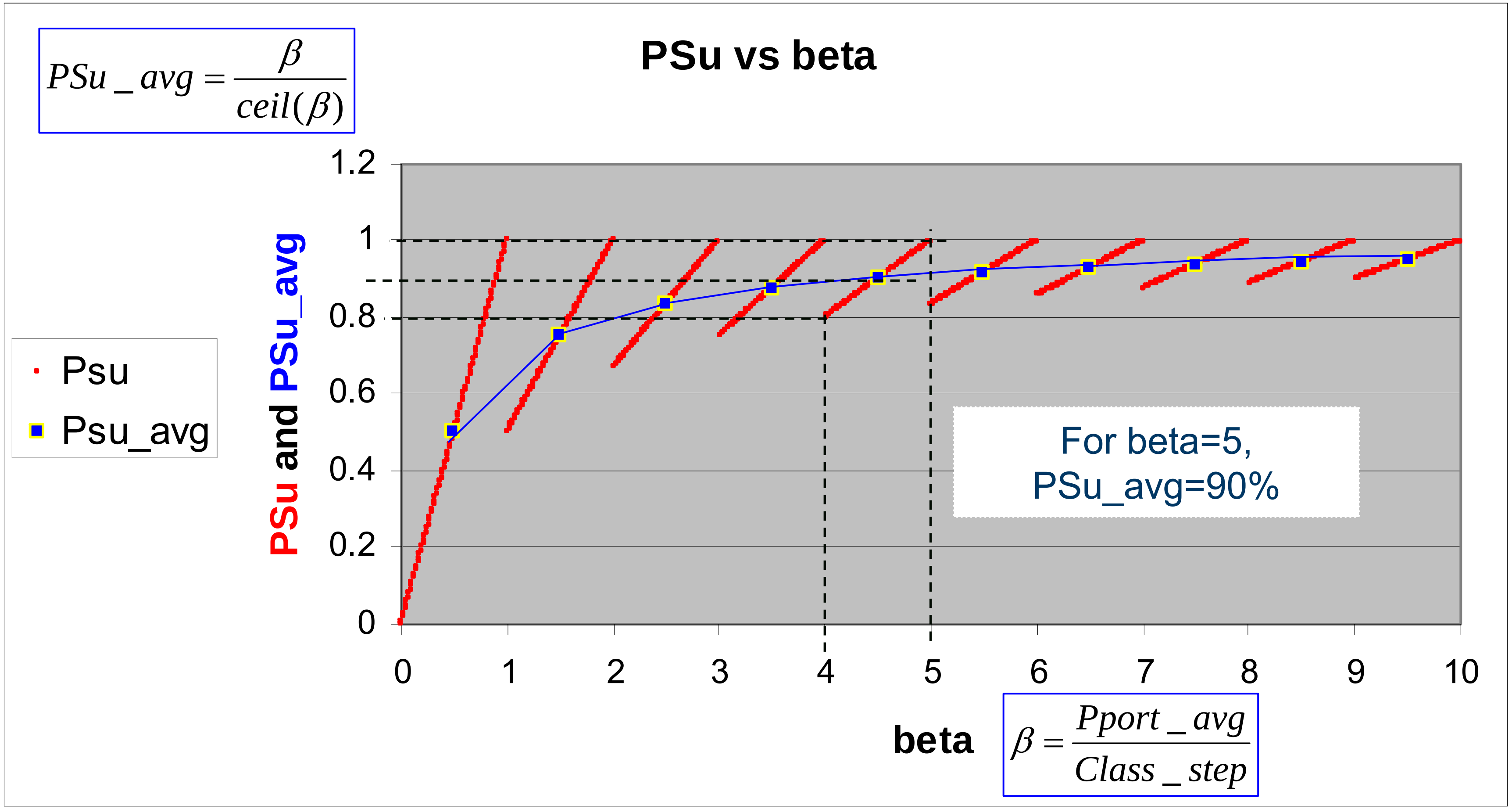
- Eq-14 $$PSu\_avg = \frac{Pport\_avg}{Class\_avg}$$

- So far we see that in <u>average</u>:
  - PSu is not function of N
  - PSu is not a function of the Pbudget
  - Knowing the probability function has advantages for setting Pport_avg however it is not required for now.
  - Moreover the probability function is a random variable itself from a the standard point of view .. therefore we used the averaging method and the whole process in order to identify, map and address the unknown variables. We later see that Pport_avg is a Marketing question and discuss how to address it.

Analysis Summary..

- $$PSu\_avg = \frac{Pport\_avg}{Class\_avg}$$ Eq-14
- Inserting class information Eq-11, to Eq-14:
- Eq-15 $$PSu\_avg = \frac{Pport\_avg}{\left(ceil\left(\frac{Pport\_avg_i}{Class\_step}\right)\right) \cdot Class\_step}$$
- Eq-16 $$\beta = \frac{Pport\_avg}{Class\_step}$$
- Eq-17 $$PSu\_avg = \frac{\beta}{ceil(\beta)}$$

Analysis Summary..



Sensitivity analysis and results

$\Delta\beta = 1$

Line	β min	β max	Psu avg	d(Psu avg)/d(β)
1	0	1	0.500	
2	1	2	0.753	25.25%
3	2	3	0.835	8.25%
4	3	4	0.876	4.12%
5	4	5	0.901	2.47%
6	5	6	0.917	1.65%
7	6	7	0.929	1.18%
8	7	8	0.938	0.88%
9	8	9	0.945	0.69%
10	9	10	0.950	0.55%
11	10	11	0.955	0.45%
12	11	12	0.959	0.37%
13	12	13	0.962	0.32%
14	13	14	0.965	0.27%
15	14	15	0.967	0.24%
16	15	16	0.969	0.21%

$$\frac{\Delta PSu\_avg}{\Delta\beta} = 0.82\%$$

Table -2

Conclusions

- PSu=100% for any integer of $\beta = \frac{Pport\_avg}{Class\_step}$ with low probability.
- PSU<100% for any positive non integer β hence:

$$PSu\_avg < \frac{\beta}{ceil(\beta)} = \frac{Pport\_avg}{Class\_step \cdot ceil(\beta)}$$

- The requirements for class_step is:

  0 <β <βmax for the desired PSu_avg.

$$Class\_step < \frac{Pport\_avg}{PSu\_avg \cdot ceil(\beta)}$$

- βmax is the β which $\frac{\partial PSu\_avg}{\partial \beta} < \varepsilon$ is no longer cost effective and is implementation dependent.
- Example:
- For PSu_avg=90% βmin=4, βmax=5, βavg=4.5 ==> β=5 Changing β from 5 to 6 will change PSu_avg by only 2.47%-1.65%=0.82%.
- In some class implementation, improving PSu_avg by 0.82% cost more than not utilizing additional 0.82% of the power supply capability and in some cost lees or nothing until we again cross a value of β that requires economical decision.

Conclusions..

- PSu utilization is mainly a function of the ratio between Pport_avg and the Class_Step

- The rules applied for any port number and for any Pbudget in average as long as

$$Pbudget < \sum_{i=1}^{N} Pclass\_\max_i$$

Pclass_max is the class value of Pport_max which is the maximum possible port power.If otherwise, power management is not required due to the fact that PSE power supply supports all ports with max power.

Proposed Design Procedure

Set Psu_avg ↔

How to determine Psu
1. System considerations
1.1 How much spare to keep in PSE PS
1.2 Etc.
2. Cost considerations
2.1 How much (1-Psu) costs?
2.2 Etc.

↓

Select β from Table 2

↓

Select Pport_avg ↔

How to determine Pport_avg
1. What is the minimum average power that we would like to support under power management environment. (Ask Marketing..)
1.1 Example: Does minimum average power per port of 5W reflects market needs

↓

Calculate Class_step

$$Class\_step = \frac{Pport\_avg}{PSu\_avg \cdot ceil(\beta)}$$

→

Calculate Number of Classes =Pport_max/Class_step

↕

Pport_max will be set by the IEEE802.3poep

Example of setting the whole package

- If we want to support N=48 port a system with:
- Pport_max=40W. (Example)
- K1=0.1. (10% of the ports get max power)
- K2=0.2. (90% of the ports get 0.2*40W=8W)
- K3=0.5 (The probability that a PD will be connected to the port and request the power. Example only.)

- Then:
- Pbudget=0.5*40*(0.1*48+0.9*48*0.2)=269W
- Pport_avg=269/48=5.6W. **(or get better umbers from Marketing..)**
- Assuming we need PSu_avg=90% ==> β=5
- Class_step=Pport_avg/(PSu_avg*ceil(β))= 5.6/(0.9*5)=1.24W
- Pclass_avg=ceil(5.6/1.24)*1.24=5.6W which is OK (guaranties that PSu can get 100% but the PSu_avg is 90%.
- Number of classes=40/1.24 = 32-33.

Summary

- A set of design rules where presented for optimizing system power management by optimizing PSu, Class_step, and the number of classes required.

- It is recommended to set a specification for the classification function and use it to filter out those implementations that do not meet it.
  - It will save us time
- The class resolution is a function of the minimum Port_avg that is needed to be supported and PSu_avg
  - minimum Pport_avg is a Marketing question.
- No need for “very high” class resolution.
  - It may cost more than the cost saved in the PSE PS.
  - higher resolution cost is also class implementation dependent
  - We need only to set optimum numbers by using the proposed design procedure

- Discussion?

Annex A

- Prior to the power up of the PD, PD Classification is the only available data for power allocation.
  - Power allocation which is not based on the above concept is not permitted by the IEEE802.3af (33.2.9).
  - Other concepts permitted only as “additional information” to the classification method i.e after power up additional source of information can be used.
  - From backwards compatibility reasons it will be reasonable to assume that similar requirements will be applied in the IEEE802.3poep
- The reasons for the above concept adopted by the IEEE802.3af are:
  - PSE need to know prior powering the PD that there is enough power left in order to prevent system shut down in case of multiple events
  - PSE can not rely only on data path since it need to support Midspan’s too.
  - PSE-PD business should be take care off on the power path in common mode to the data to prevent dependence.