
TNO innovation for life

# Field performance of vectored VDSL2

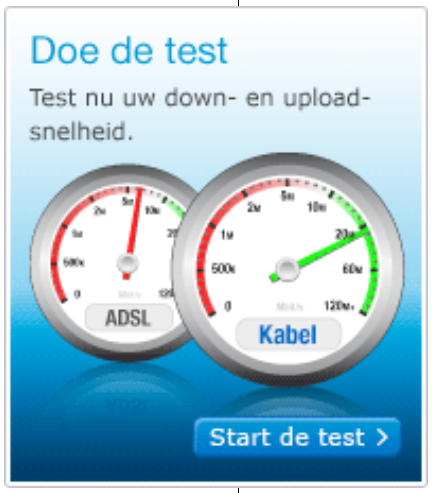
Delivering 100+ Mbps to the masses

DSL Seminar, June 17th 2015

B.M. van den Heuvel
(with contributions from J.J. Boschma)


# Contents

# A word from our esteemed competitors





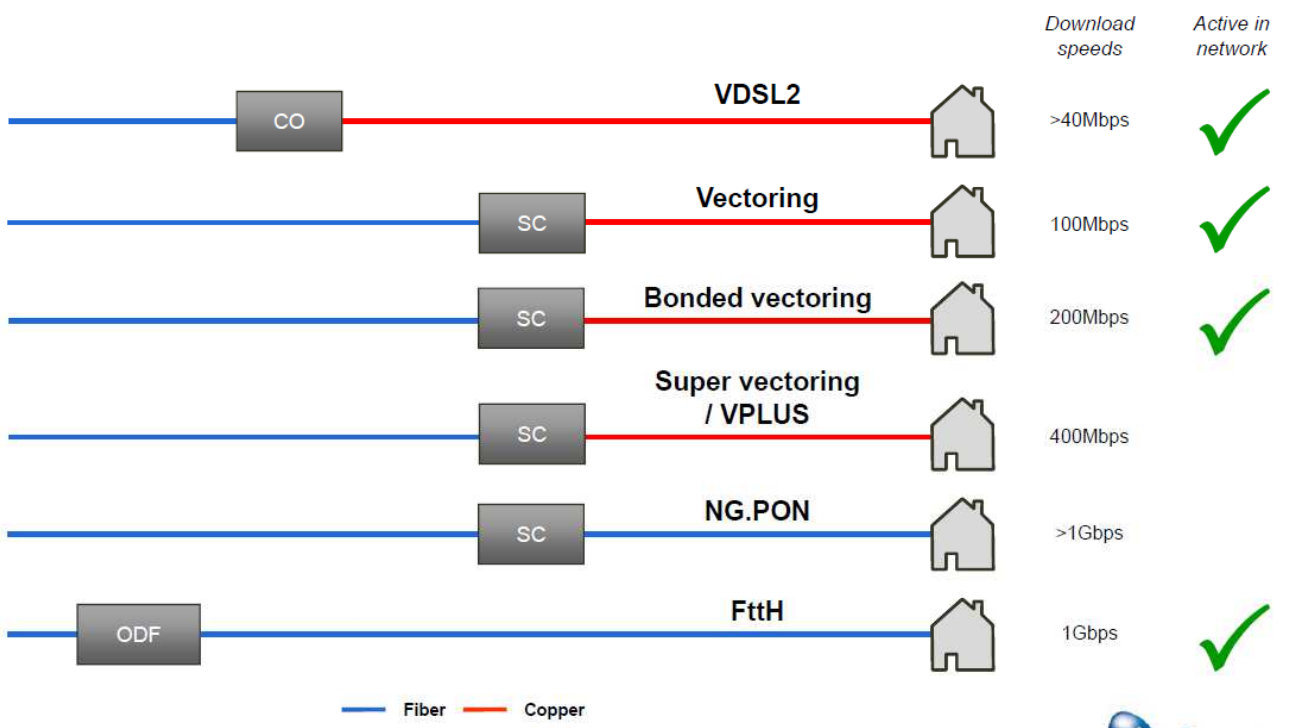




# Vectoring deployment in the Netherlands

## Capacity - fixed network (cont'd)

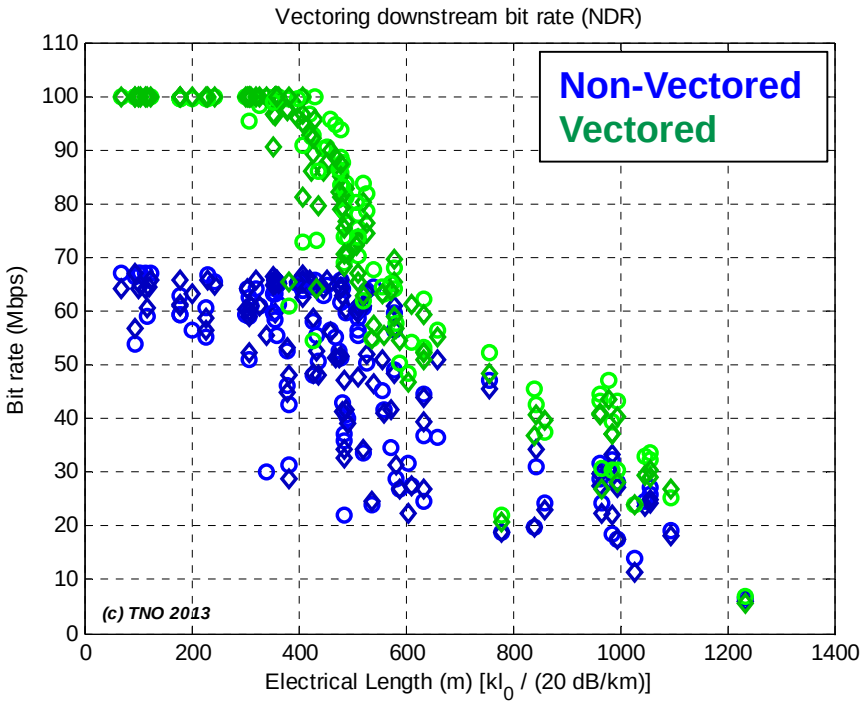
Technological developments driving higher future bandwidth



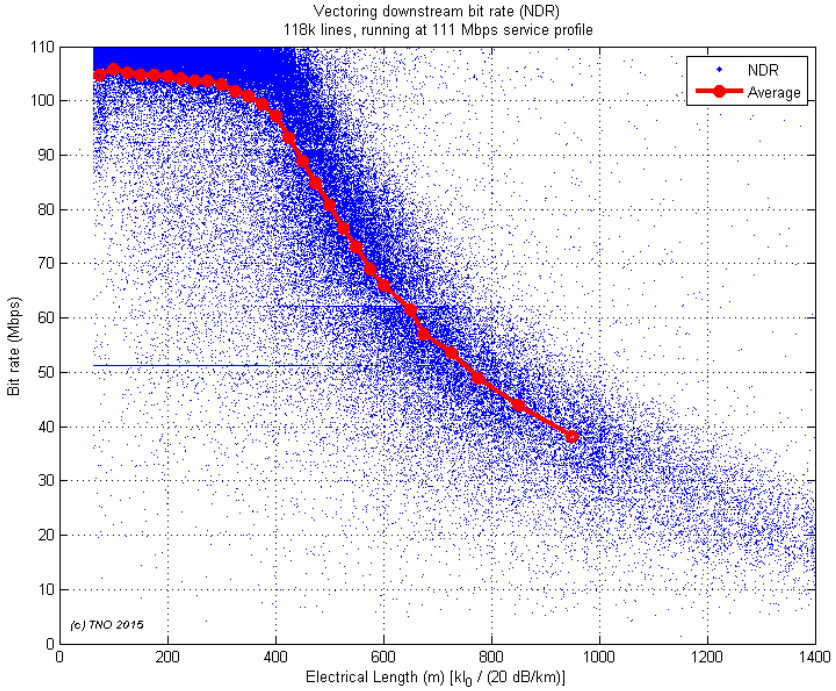

Source: KPN, *Fourth Quarter and Annual Results 2014*, February 4th, 2015.

# Contents

# Vectoring deployment in the Netherlands

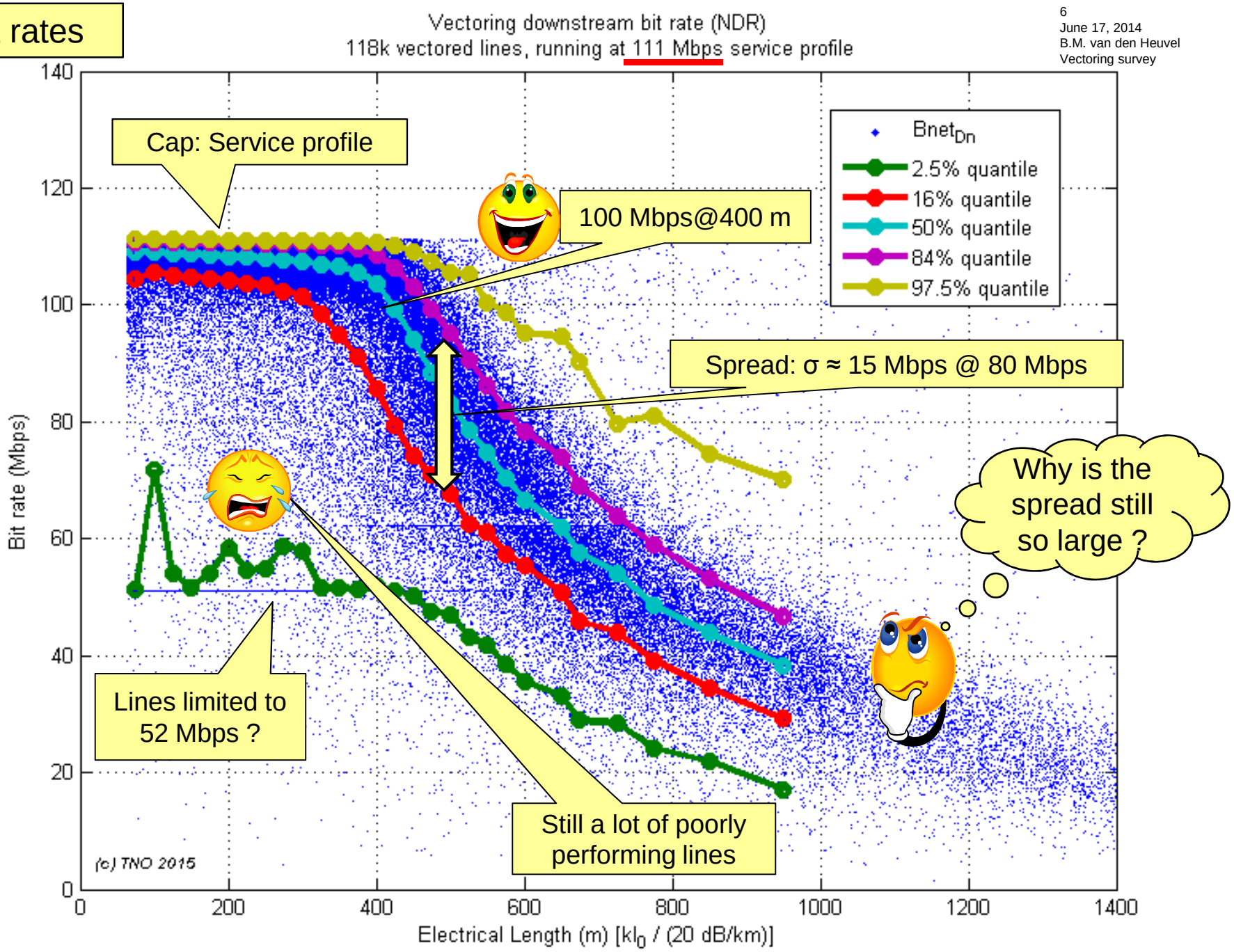



2012:
Technical Development Trial
120 lines at 2 DSLAMs

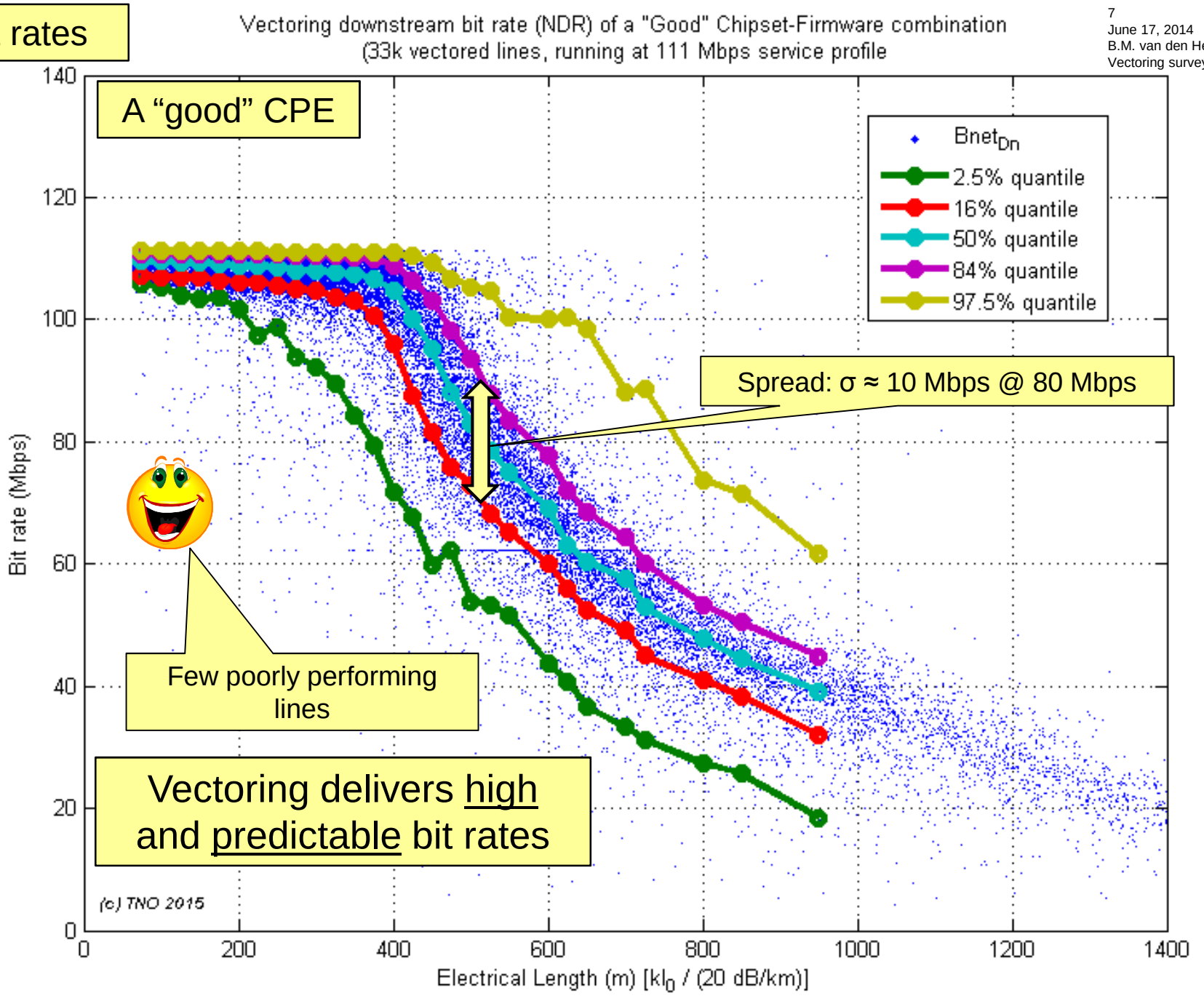



2014
Commercial deployment
183.000 lines at 2830 DSLAMs

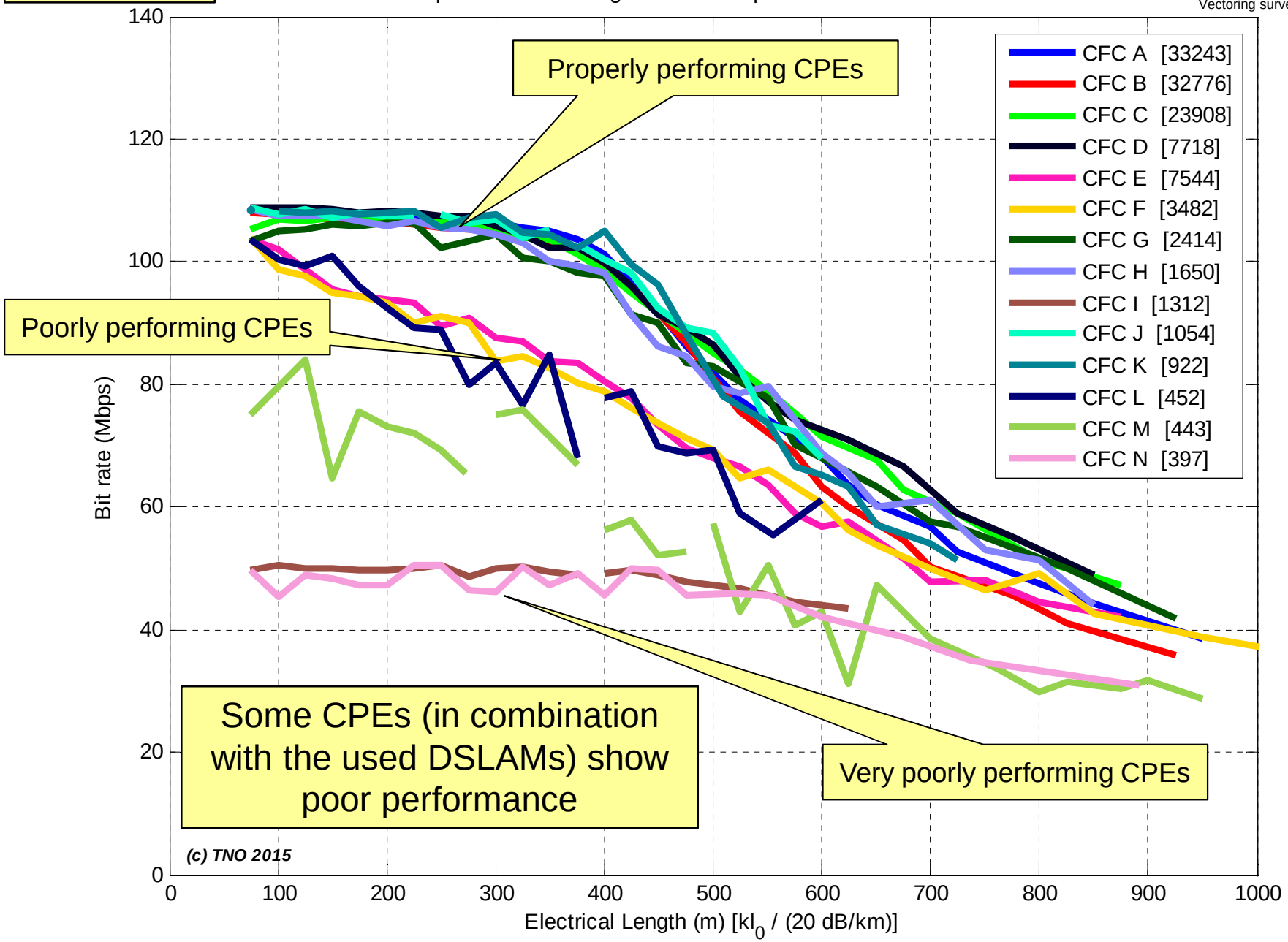
# Bit rates


Vectoring downstream bit rate (NDR)
118k vectored lines, running at 111 Mbps service profile
Cap: Service profile
100 Mbps@400 m
Spread: σ ≈ 15 Mbps @ 80 Mbps
Why is the spread still so large ?
Lines limited to 52 Mbps ?
Still a lot of poorly performing lines
(c) TNO 2015
Bnet_Dn
2.5% quantile
16% quantile
50% quantile
84% quantile
97.5% quantile
Bit rate (Mbps)
Electrical Length (m) [kl0 / (20 dB/km)]
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
1200
1400

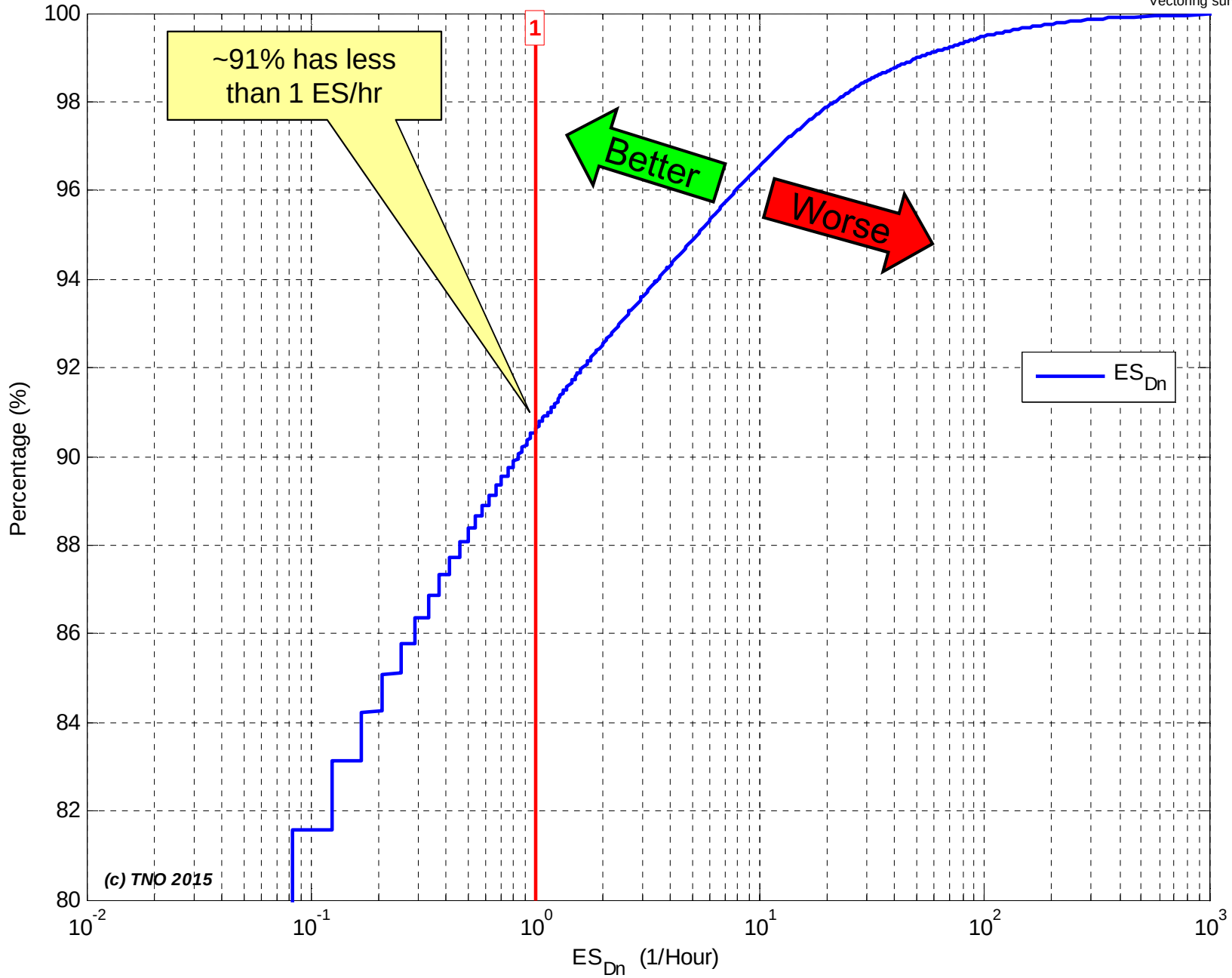
# Bit rates


Vectoring downstream bit rate (NDR) of a "Good" Chipset-Firmware combination
(33k vectored lines, running at 111 Mbps service profile
A “good” CPE
Bnet$_{Dn}$
2.5% quantile
16% quantile
50% quantile
84% quantile
97.5% quantile
Spread: σ ≈ 10 Mbps @ 80 Mbps
Few poorly performing lines
Vectoring delivers high and predictable bit rates
(c) TNO 2015
Bit rate (Mbps)
Electrical Length (m) [kl$_0$ / (20 dB/km)]
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
1200
1400

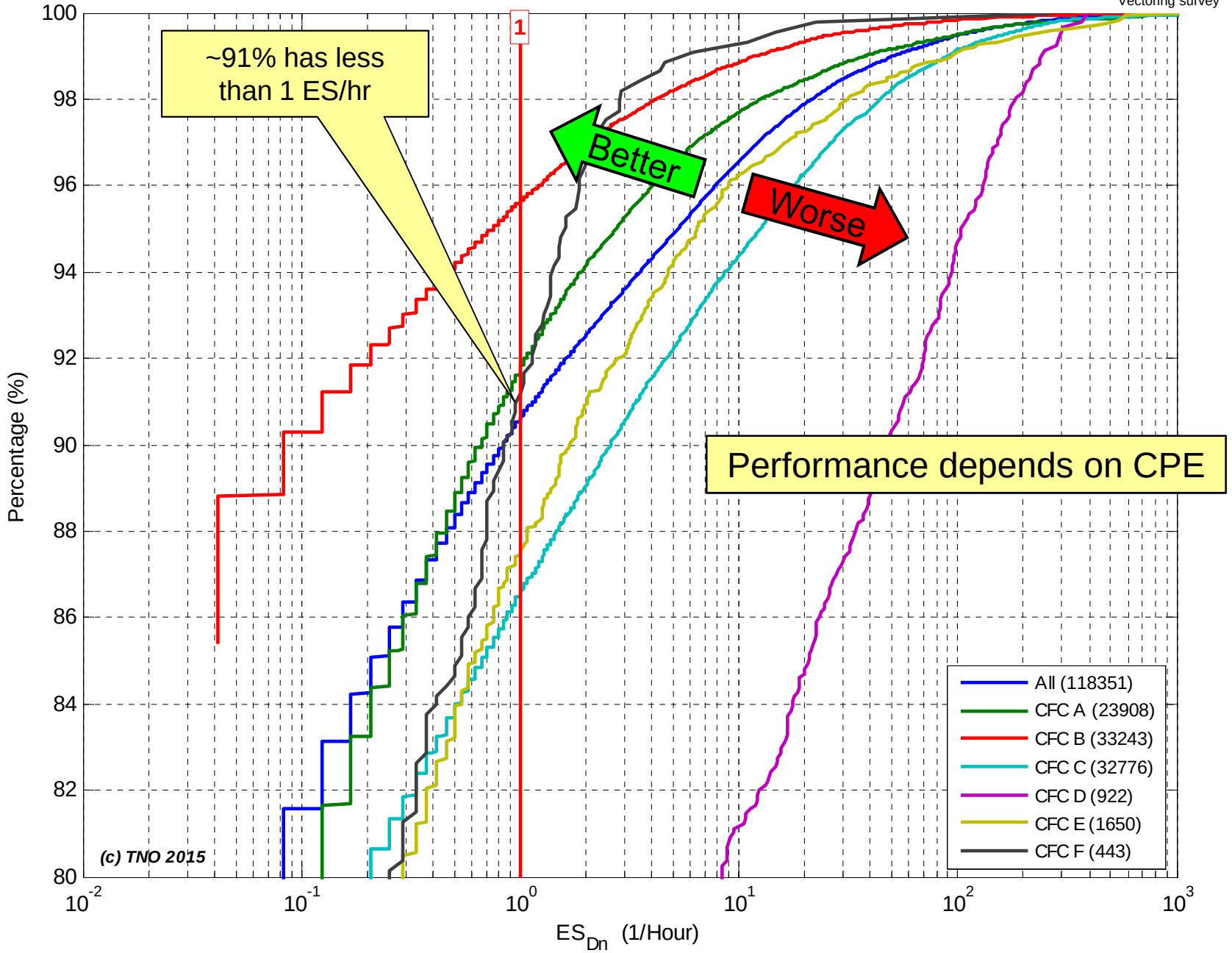
# Bit rates


Dependence of average NDR on Chipset-Firmware Combination
Properly performing CPEs
Poorly performing CPEs
Some CPEs (in combination with the used DSLAMs) show poor performance
Very poorly performing CPEs
CFC A [33243]
CFC B [32776]
CFC C [23908]
CFC D [7718]
CFC E [7544]
CFC F [3482]
CFC G [2414]
CFC H [1650]
CFC I [1312]
CFC J [1054]
CFC K [922]
CFC L [452]
CFC M [443]
CFC N [397]
Bit rate (Mbps)
Electrical Length (m) [kl0 / (20 dB/km)]
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800
900
1000
(c) TNO 2015

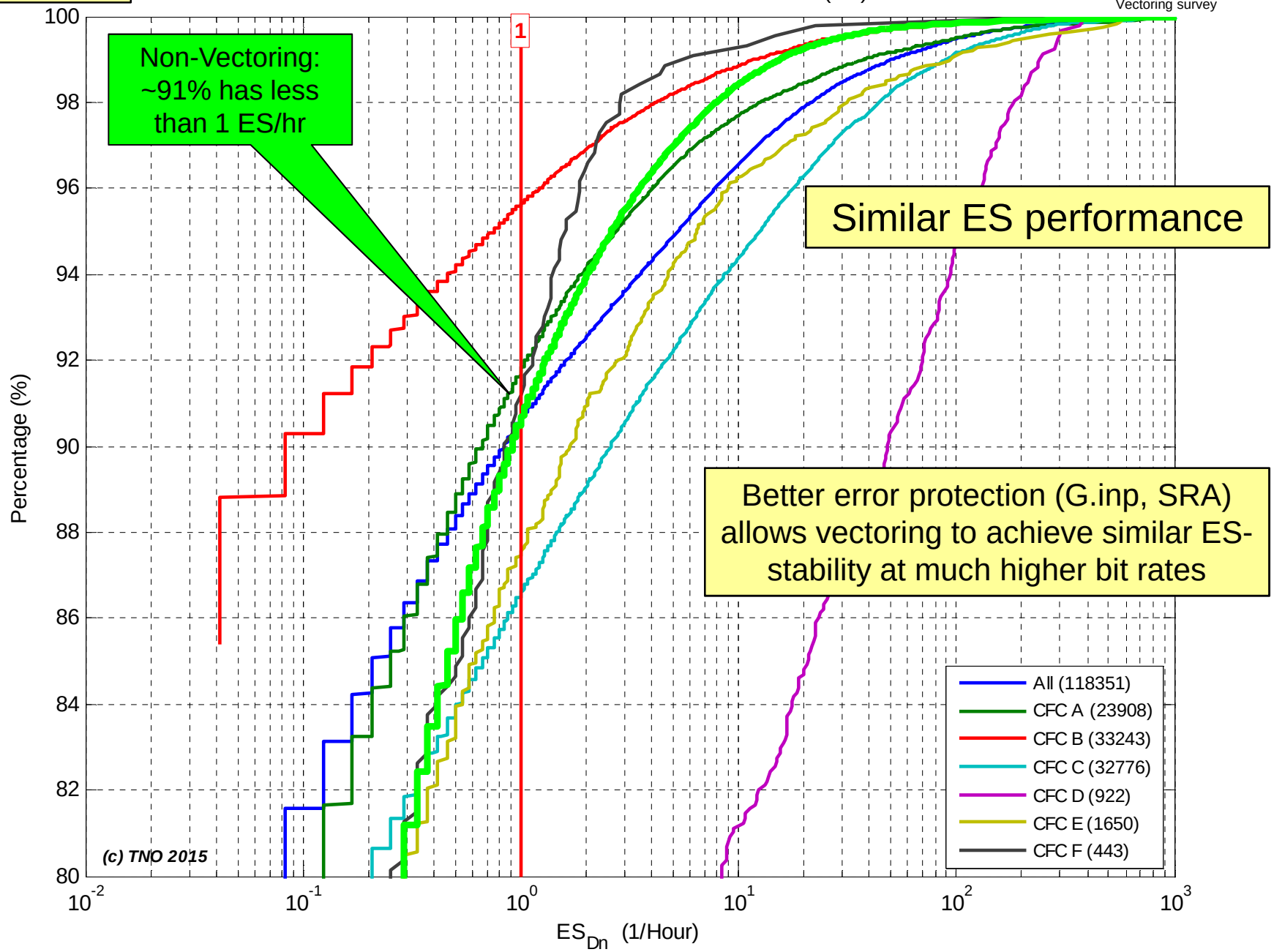
# Stability


Distribution of downstream Errored Seconds (ES)
~91% has less than 1 ES/hr
1
Better
Worse
ES_Dn
Percentage (%)
ES_Dn (1/Hour)
100
98
96
94
92
90
88
86
84
82
80
10^-2
10^-1
10^0
10^1
10^2
10^3
(c) TNO 2015

# Stability

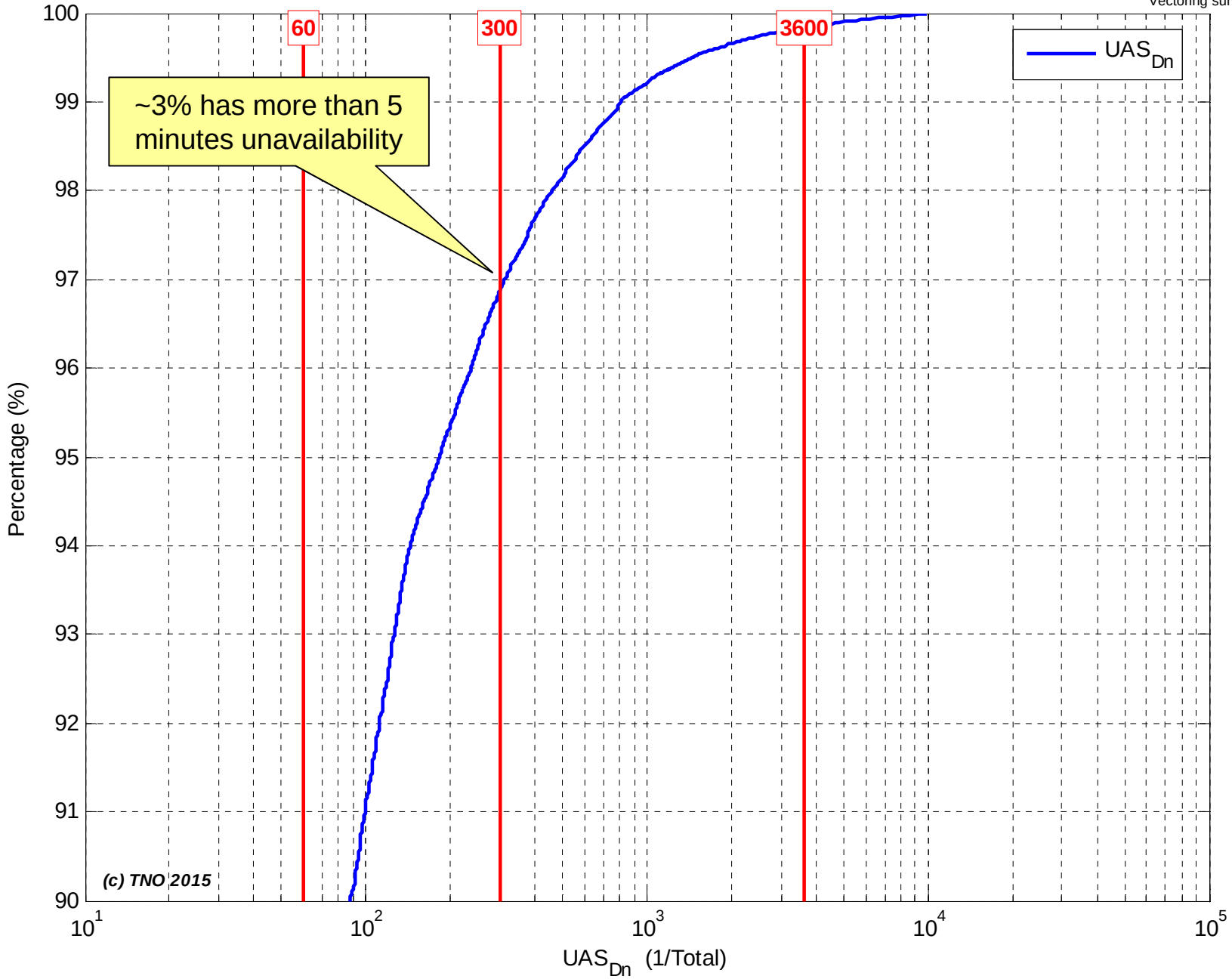

Distribution of downstream Errored Seconds (ES)
~91% has less than 1 ES/hr
1
Better
Worse
Performance depends on CPE
Percentage (%)
100
98
96
94
92
90
88
86
84
82
80
$10^{-2}$
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$
$10^{3}$
$ES_{Dn}$ (1/Hour)
All (118351)
CFC A (23908)
CFC B (33243)
CFC C (32776)
CFC D (922)
CFC E (1650)
CFC F (443)
(c) TNO 2015

# Stability


Distribution of downstream Errored Seconds (ES)
Non-Vectoring:
~91% has less
than 1 ES/hr
1
Similar ES performance
Better error protection (G.inp, SRA)
allows vectoring to achieve similar ES-
stability at much higher bit rates
All (118351)
CFC A (23908)
CFC B (33243)
CFC C (32776)
CFC D (922)
CFC E (1650)
CFC F (443)
Percentage (%)
100
98
96
94
92
90
88
86
84
82
80
10^-2
10^-1
10^0
10^1
10^2
10^3
ES_Dn (1/Hour)
(c) TNO 2015

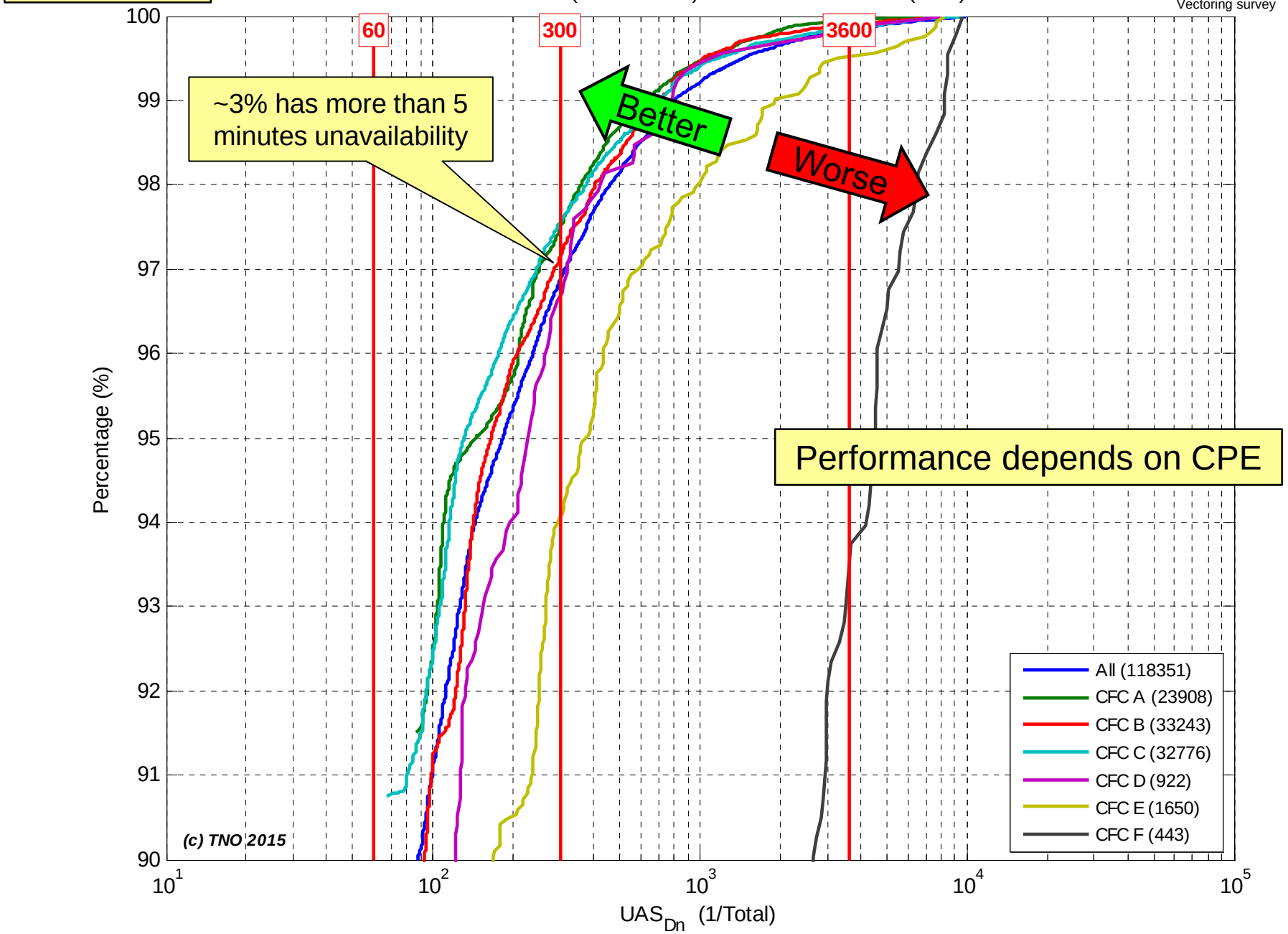
# Stability





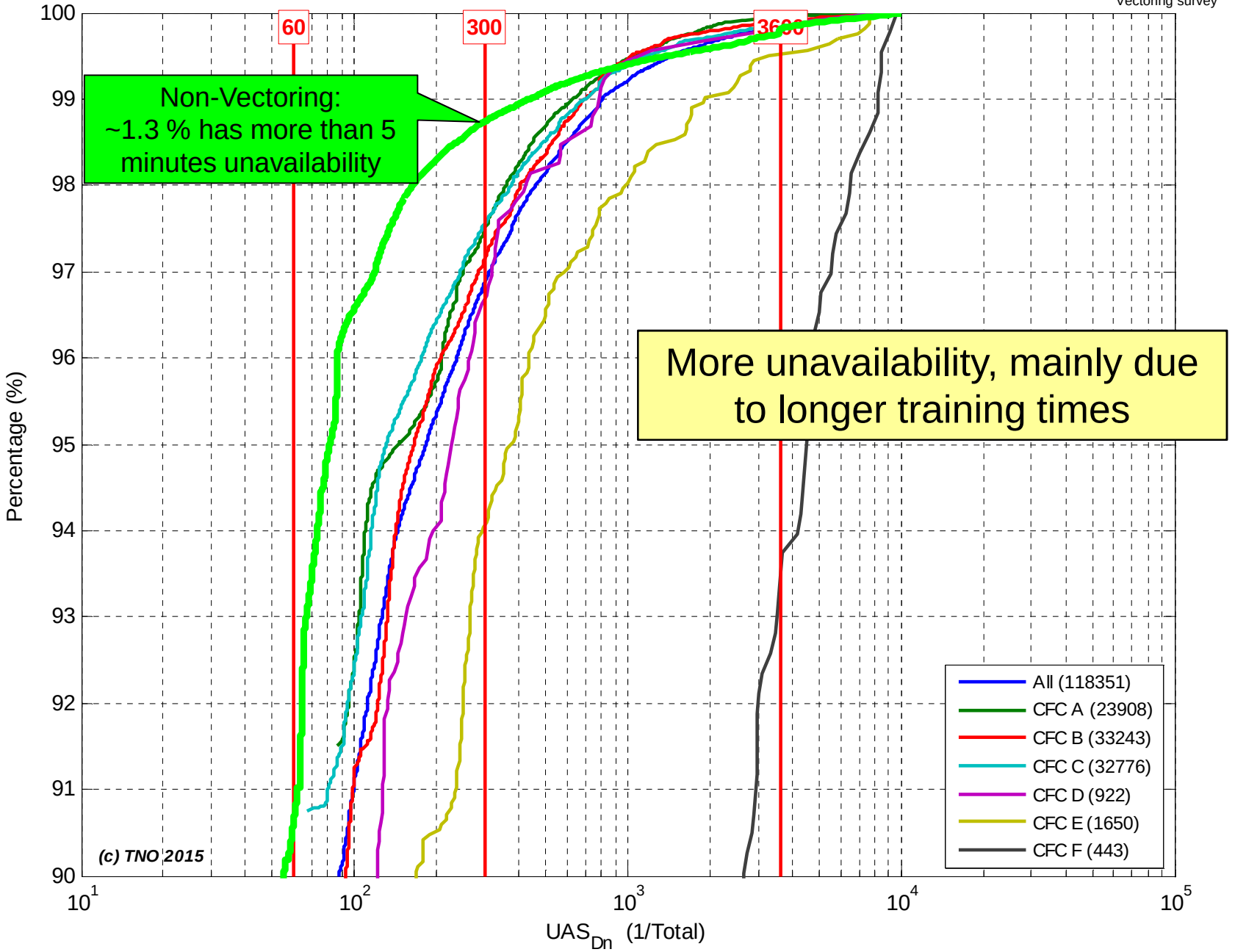

Lines with more than 10000 UAS/day were excluded.

# Stability




Lines with more than 10000 UAS/day were excluded.

# Stability




Lines with more than 10000 UAS/day were excluded.


TNO innovation for life

# Observations from Survey

- Bit rates: Vectoring delivers high and predictable bit rates
- Stability: Comparable to non-vectoring, but higher unavailability due to longer training times
- Large performance differences between different CPEs (chipset-firmware combinations)

Vectoring in the field is doing a good job !

# Contents

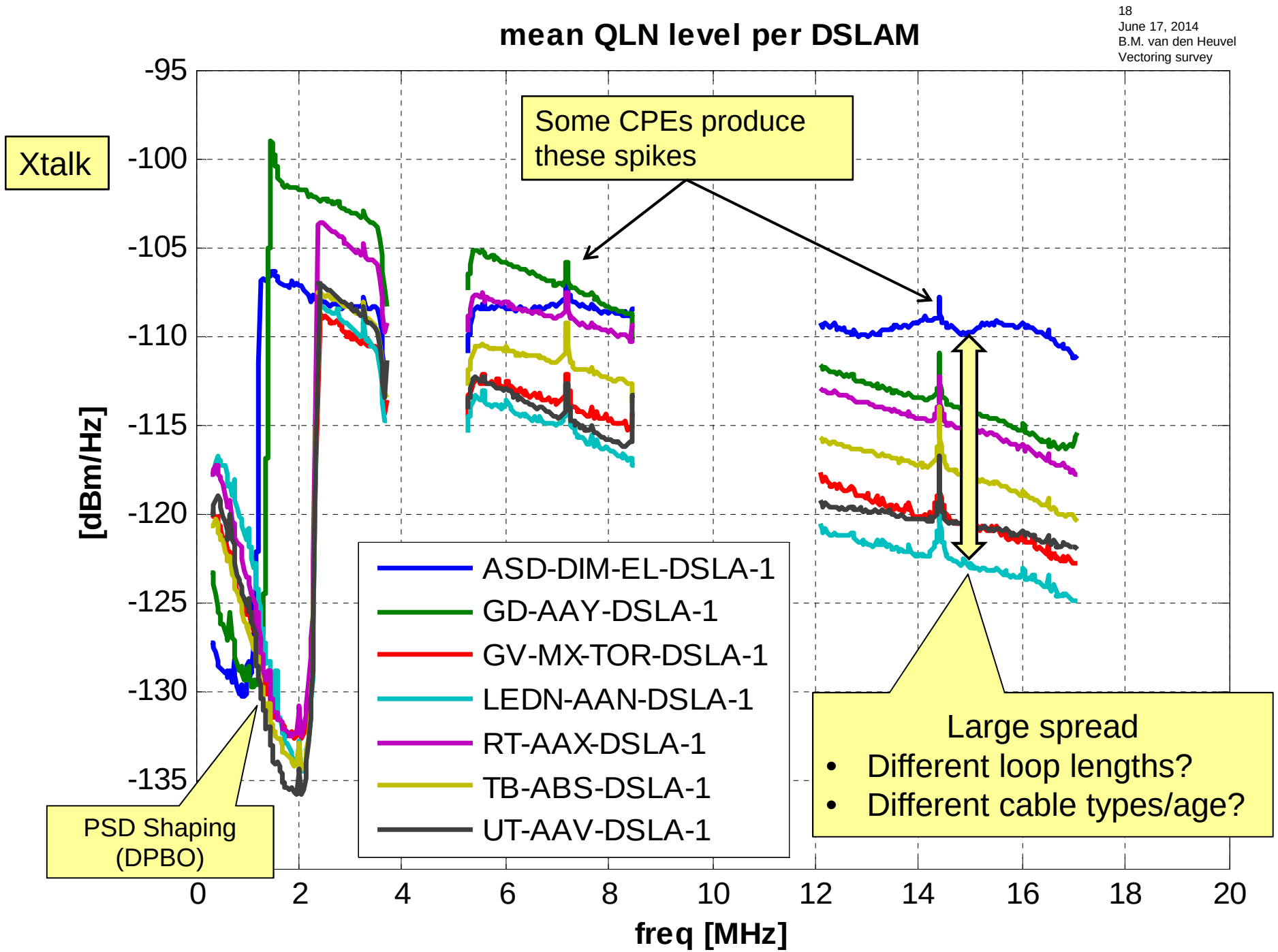


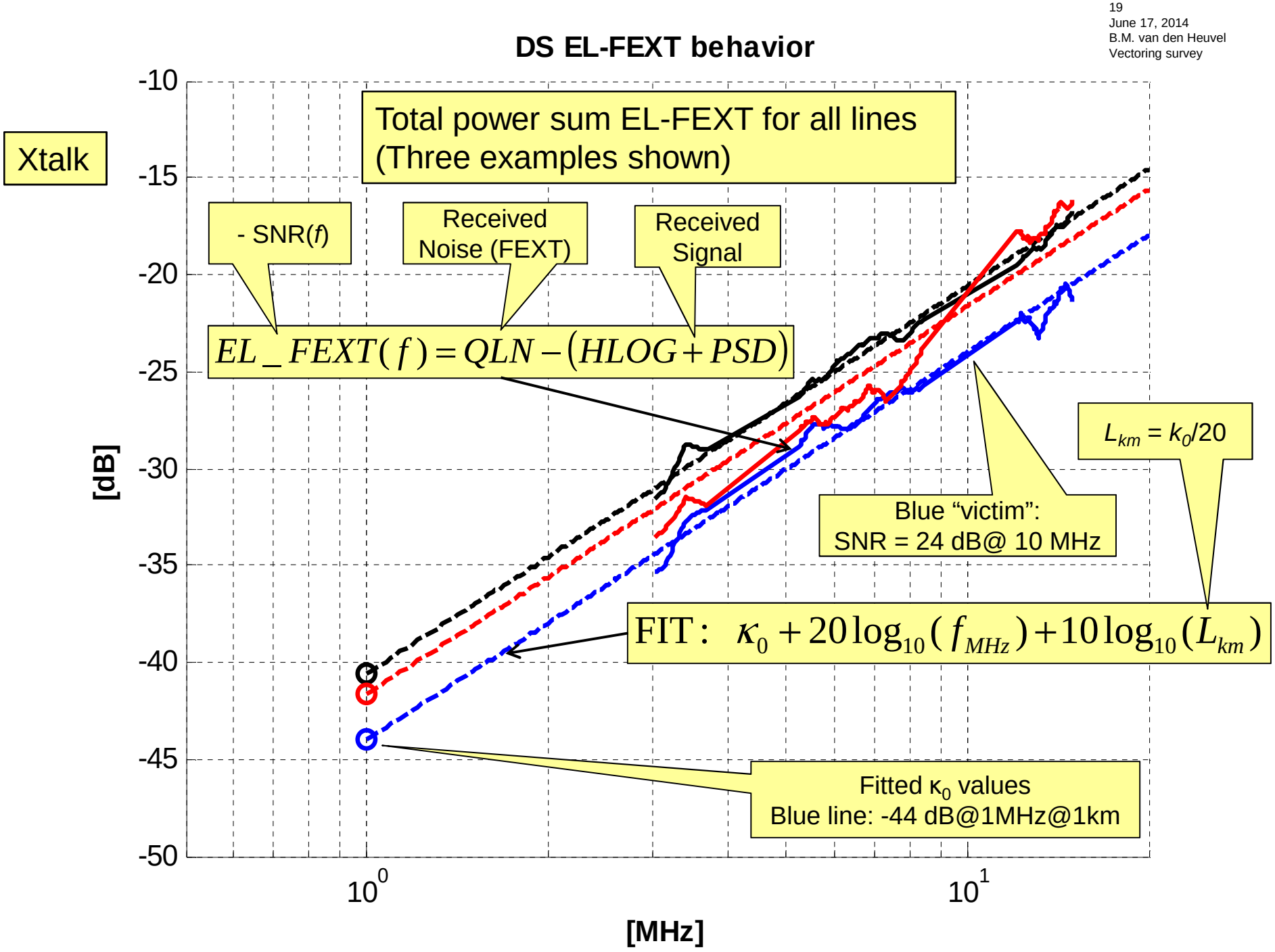
TNO innovation for life

Xtalk

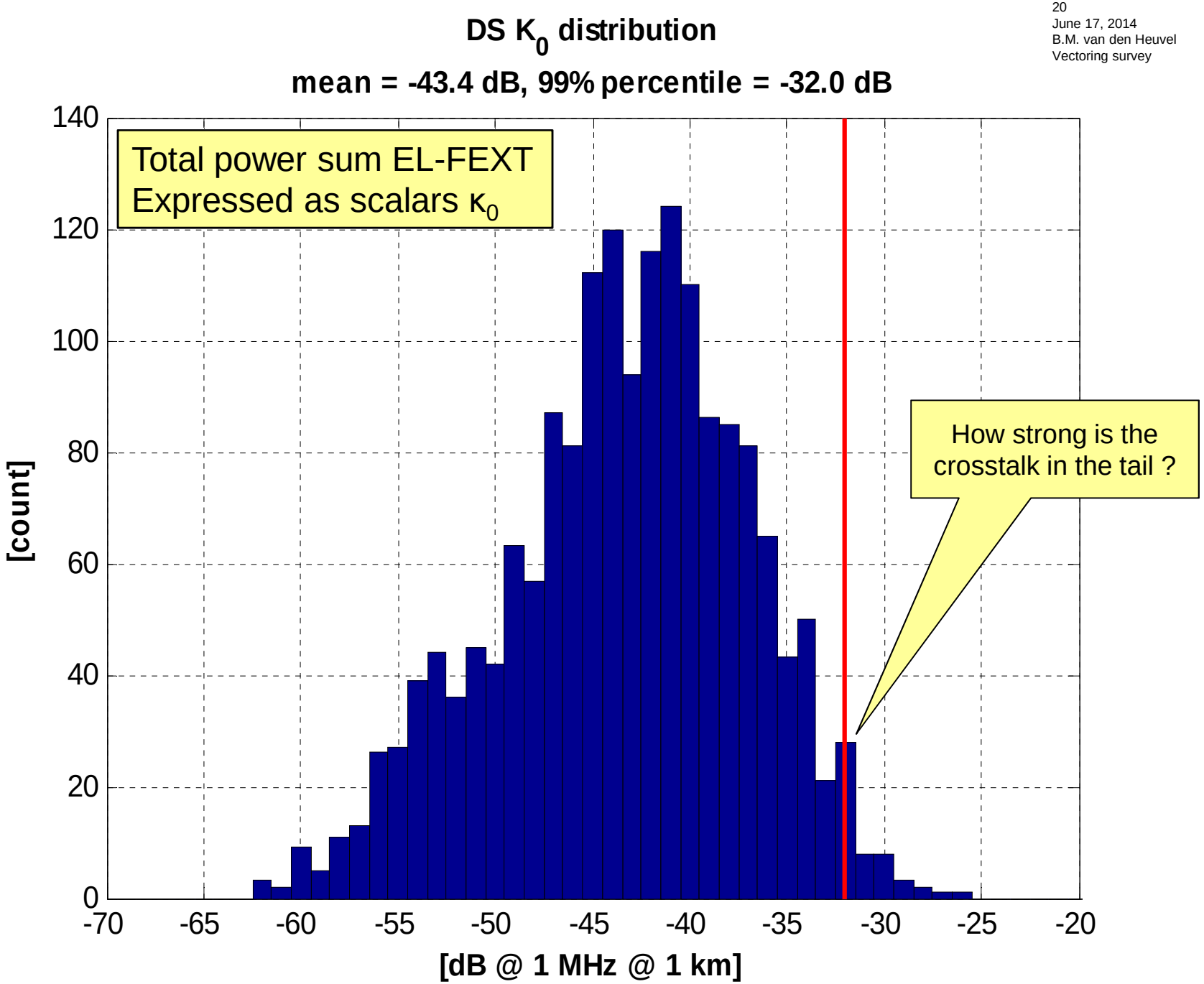
# Crosstalk level analysis

- DMT-carrier data from 1748 vectored VDSL2 lines on seven DSLAMs
- Quite Line Noise (QLN(f)) → Received Noise
- Loop attenuation (HLOG(f))→ Received Signal
- Together: Signal-to-Noise ratio
- Purpose: Insights into required crosstalk suppression by vectoring
  - Under what crosstalk regime is vectoring required to work ?


mean QLN level per DSLAM
Xtalk
Some CPEs produce these spikes
[dBm/Hz]
freq [MHz]
-95
-100
-105
-110
-115
-120
-125
-130
-135
0
2
4
6
8
10
12
14
16
18
20
ASD-DIM-EL-DSLA-1
GD-AAY-DSLA-1
GV-MX-TOR-DSLA-1
LEDN-AAN-DSLA-1
RT-AAX-DSLA-1
TB-ABS-DSLA-1
UT-AAV-DSLA-1
PSD Shaping (DPBO)
Large spread
• Different loop lengths?
• Different cable types/age?


DS EL-FEXT behavior
Xtalk
Total power sum EL-FEXT for all lines
(Three examples shown)
- SNR(f)
Received
Noise (FEXT)
Received
Signal
$EL\_FEXT(f) = QLN - (HLOG + PSD)$
$L_{km} = k_0/20$
Blue "victim":
SNR = 24 dB@ 10 MHz
FIT: $\kappa_0 + 20\log_{10}(f_{MHz}) + 10\log_{10}(L_{km})$
Fitted $\kappa_0$ values
Blue line: -44 dB@1MHz@1km
-10
-15
-20
-25
-30
-35
-40
-45
-50
[dB]
$10^0$
$10^1$
[MHz]

Xtalk


DS $K_0$ distribution
mean = -43.4 dB, 99% percentile = -32.0 dB
Total power sum EL-FEXT
Expressed as scalars $\kappa_0$
How strong is the crosstalk in the tail ?
[count]
[dB @ 1 MHz @ 1 km]
0
20
40
60
80
100
120
140
-70
-65
-60
-55
-50
-45
-40
-35
-30
-25
-20


TNO innovation for life

Xtalk

# EL-FEXT (99% worst-case values, @1MHz@1km)

| | Pair-pair EL-FEXT | Total EL-FEXT |
|---|---|---|
| Previous Slide | n/a | -32 dB |
| Belgacom/Proximus* | n/a | -29 dB |

* Similar methodology presented at TNO DSL Seminar 2012.
Using vectoring MIB data leads to comparable results.
See als Belgacom/Proximus ITU contributions 2015-02-Q4-033, 2015-04-Q4-040


TNO innovation for life

Xtalk

# EL-FEXT (99% worst-case values, @1MHz@1km)

| | Pair-pair EL-FEXT | Total EL-FEXT |
|---|---|---|
| Previous Slide | n/a | -32 dB |
| Belgacom/Proximus | n/a | -29 dB |
| Traditional assumption (ETSI/ANSI/ATIS/NIPP-NAI, etc, etc) | -45 dB * | -45 dB + 6 log (N)<br>e.g. -39 dB @ N=10<br>(FSAN model) |

Preliminary conclusion: Dutch field results broadly support earlier observations of stronger-than-assumed crosstalk in the field.

Caveat: (statistical) approach and definitions may be somewhat different.

* For Dutch Spectral Management studies, a value of -37.4 dB is used



TNO innovation for life

Xtalk

# Is stronger-than-assumed crosstalk a problem ?

For VDSL2/17a:

- Strong crosstalk may explain part of the remaining spread in vectoring performance

For VDSL2/35b:

- Crosstalk even stronger when going to 35 MHz
- -32 dB@1MHz → -1 dB@35 MHz * (on bad lines)
- Signal level comparable to Noise Level
- This breaks the typical “diagonal dominance” vectoring assumption

* Values at 1 km. Values at e.g. 500 m will be 3 dB lower
20 dB/decade extrapolation assumption; no ‘double slope’ effect yet

TNO innovation for life

Xtalk

# Implications for VDSL2/35b

- Can VDSL2 vectoring suppress strong crosstalk sufficiently?

- Are there limitations in the vectoring protocol (ITU G.993.5 standard)?
  - Channel estimation must be able to ‘measure’ strong coupling.
  - Back-port certain ‘tricks’ from G.fast vectoring ?

→ Work ongoing in the ITU

- Are there limitations in the (proprietary) vectoring implementations?

→ Ask your vendor !

If the crosstalk in your network is large,
VDSL2/35b will require very good vectoring !


# Contents

I. Results from the performance survey vectored VDSL2

II. Crosstalk level analysis

III. Forward look: VDSL2/35b, a.k.a. “Vplus”, “Supervectoring”,…



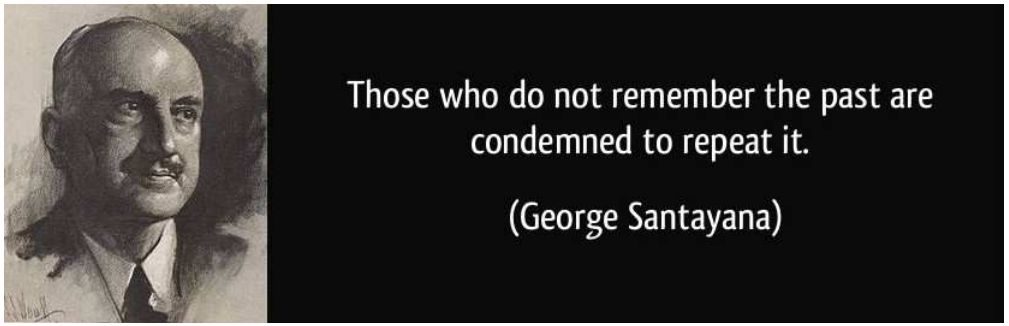

TNO innovation for life

Vplus

# Vplus… Haven't we seen this before?

- Vplus is to VDSL as ADSL2+ is to ADSL2
  - double the number of carriers
  - double the bandwidth
  - double the bitrate (on short loops)

- Upgrade of the current generation xDSL versus migrating to the next generation technology



Vplus

# From VDSL2 to Vplus

| | Then | Now |
|---|---|---|
| Current technology from existing node | ADSL(2)/CO | VDSL2/Cab |
| New technology, optimised for new, deeper node | VDSL2/Cab | G.fast/DP |
| Upgrade of existing technology | ADSL2+/CO | Vplus/Cab |
| Tendency to use new technology from existing node | VDSL2/CO | G.fast/Cab |

Operators reluctant to:
- Deploy from new sites
- Create new sites

"You can bring the operator to the technology, but you can't force him to deploy"

"It's the (business) economy, stupid"

TNO innovation for life

Vplus

# Similarities between Vplus and ADSL2+

- Short term advantages / quick wins
  - Higher (advertisement) bandwidths for a part of the market
  - Easy, backward-compatible and relatively low cost upgrade


- Postponement of investments
  - Reduces the pressure to migrate to the next generation xDSL
  - Postpones the need for deeper deployment of fiber
  - Postpones the need to create more nodes with active equipment
  - Reduces/fragmentizes (in the short term) the market for the next generation equipment

- Spectral impact on the next generation technology
  - ADSL2+/CO required PSD shaping for VDSL2/Cab: Minor performance penalty.
  - Vplus will require a start frequency for G.fast above 35+ MHz (in shared cables): Big performance penalty !



TNO innovation for life

Vplus

# History repeats?


- Will Vplus/Cab be as succesful as ADSL2+/CO ?
  - ADSL2+ enabled triple play services to a large part of the market
  - Outcome for Vplus need not be the same as for ADSL2+
- Will Vplus bring you enough bit rate? For how long?
- Should operators “bite the bullet” and migrate to G.fast/DP ?
- Will (short-term) business-economical arguments trump technical arguments ? Should they?
- Can G.fast/Cab pave the way for G.fast/DP ?
- Is a ‘per-cabinet’ approach the right way forward ?
  - E.g. Vplus for existing, ‘compact’ cabinets,
  - G.fast from (new) DPs at other places?
  - Is one man’s cabinet, another man’s DP ?

Answers depend on your network !



TNO innovation for life

# Conclusions

- Vectored VDSL2 in the field delivers high and predictable bit rates


- Stronger-than-assumed crosstalk requires very good vectoring for VDSL2/35b

- Decisions where to deploy which new xDSL technology will depend on your network


What is the role of VDSL2/35b and G.fast in your network evolution ?


TNO innovation for life

# Thank You!


TNO innovation for life

# Contact

For more information, please contact:

**Bas van den Heuvel**
*Senior Scientist*

**TNO Network Technology**
Anna van Buerenplein 1
P.O. Box 96800,
2509 JE Den Haag
The Netherlands

+31 88 8667126
bas.vandenheuvel@tno.nl