Fiber-Optic Testing Challenges in Point-to-Multipoint PON Testing

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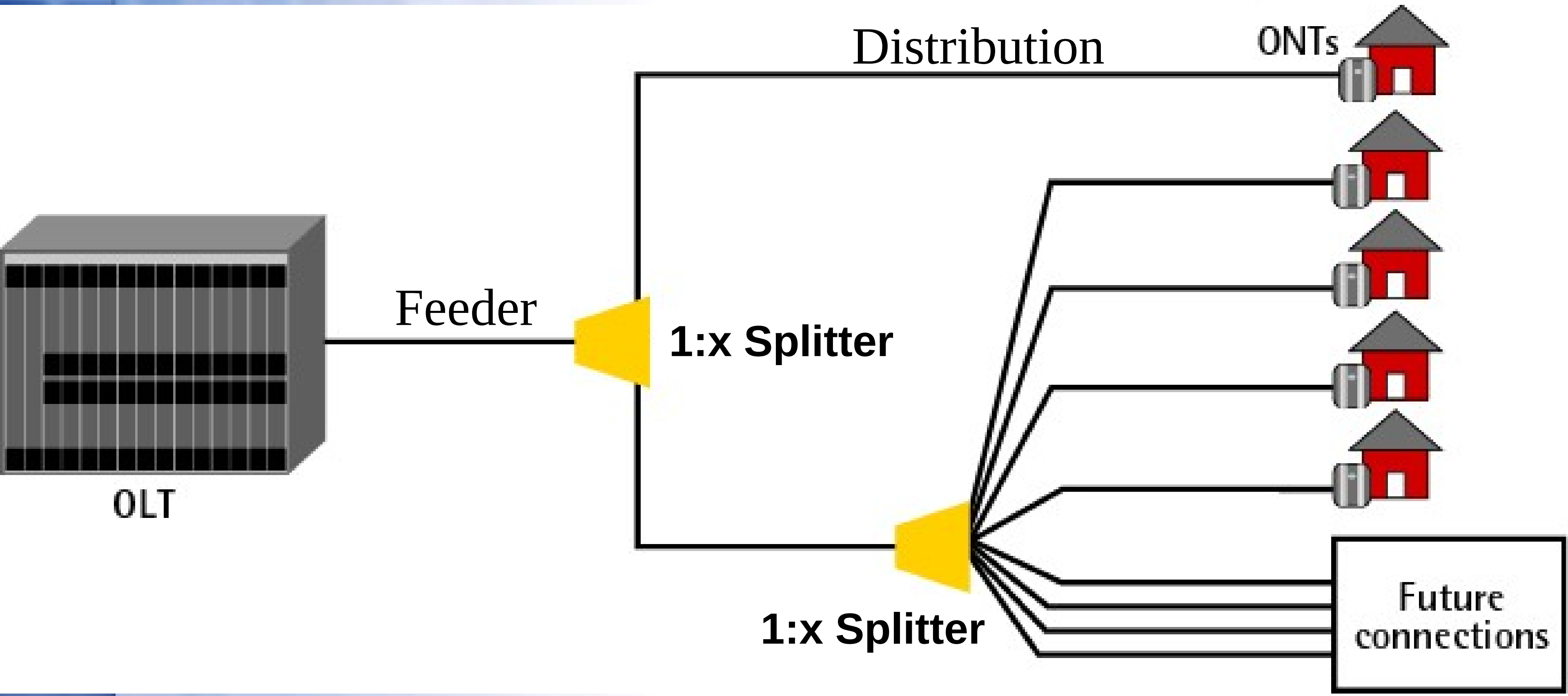
Agenda

- FTTP layouts and loss budgets
- Proposed tests at each step of the way.
  - Network and Equipment Installation Stage
  - Maintenance Stage
- Can we test with an OTDR from the OLT
- Impact of total backscattering on loss of events in a point-to-point network

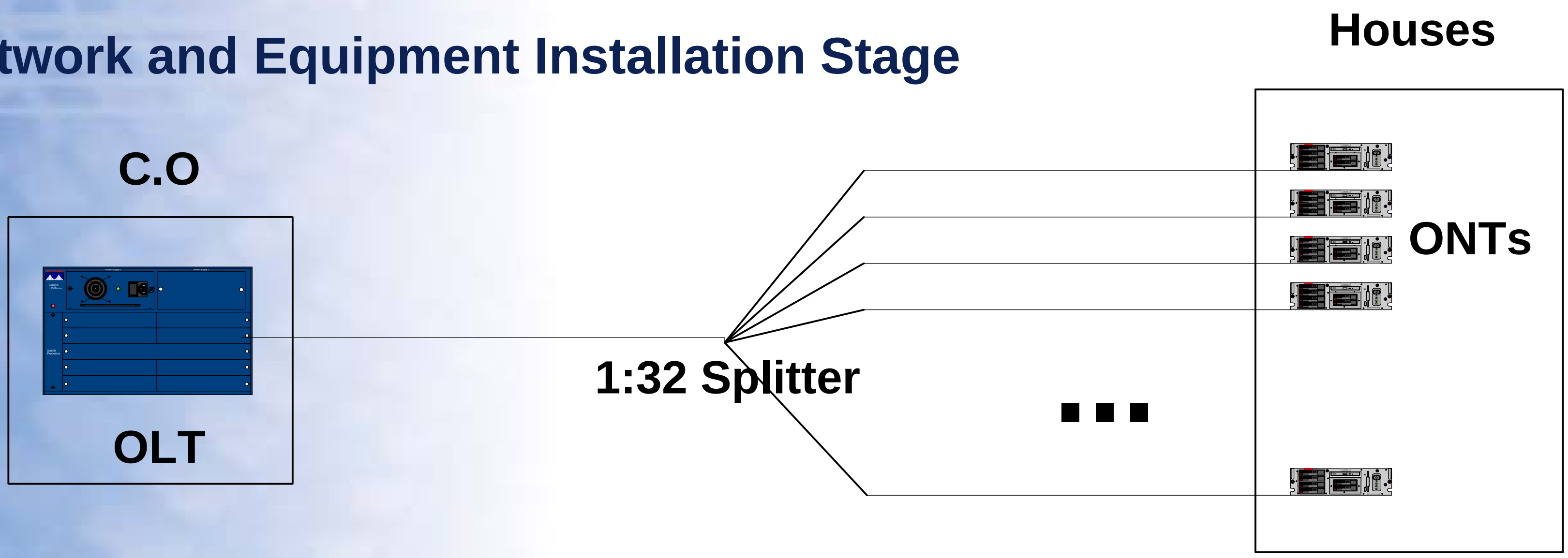
FTTP layouts and loss budgets



- 25dB total loss budget for Class-B PON
- 30dB total loss budget for Class-C PON
- High power at 1550nm

Proposed tests at each step of the way

Network and Equipment Installation Stage



Proposed Testing Steps

Step 1) Verify Total Loss Budget

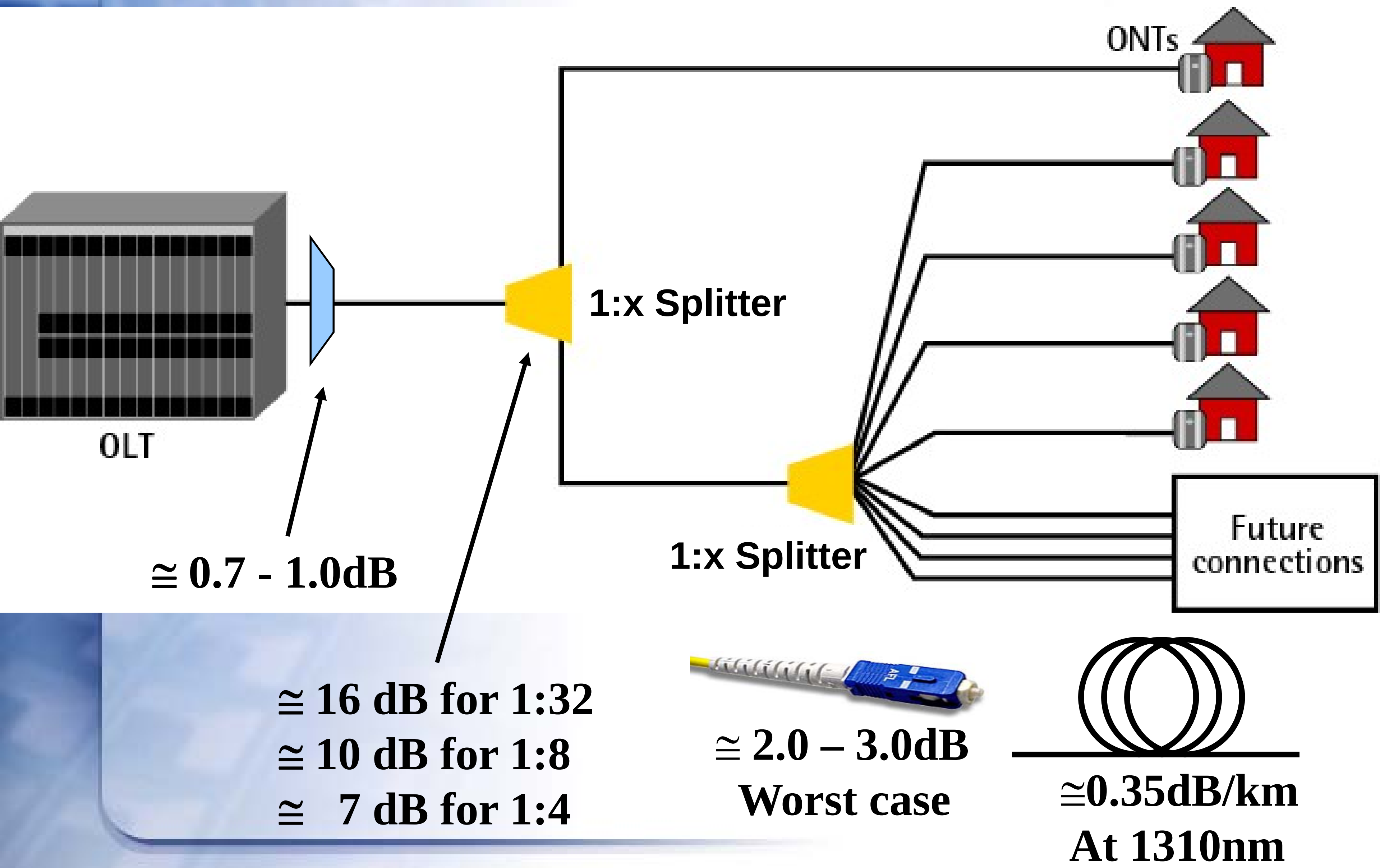
Step 2) Link Characterization

Step 3) Coupler and Splices Characterization

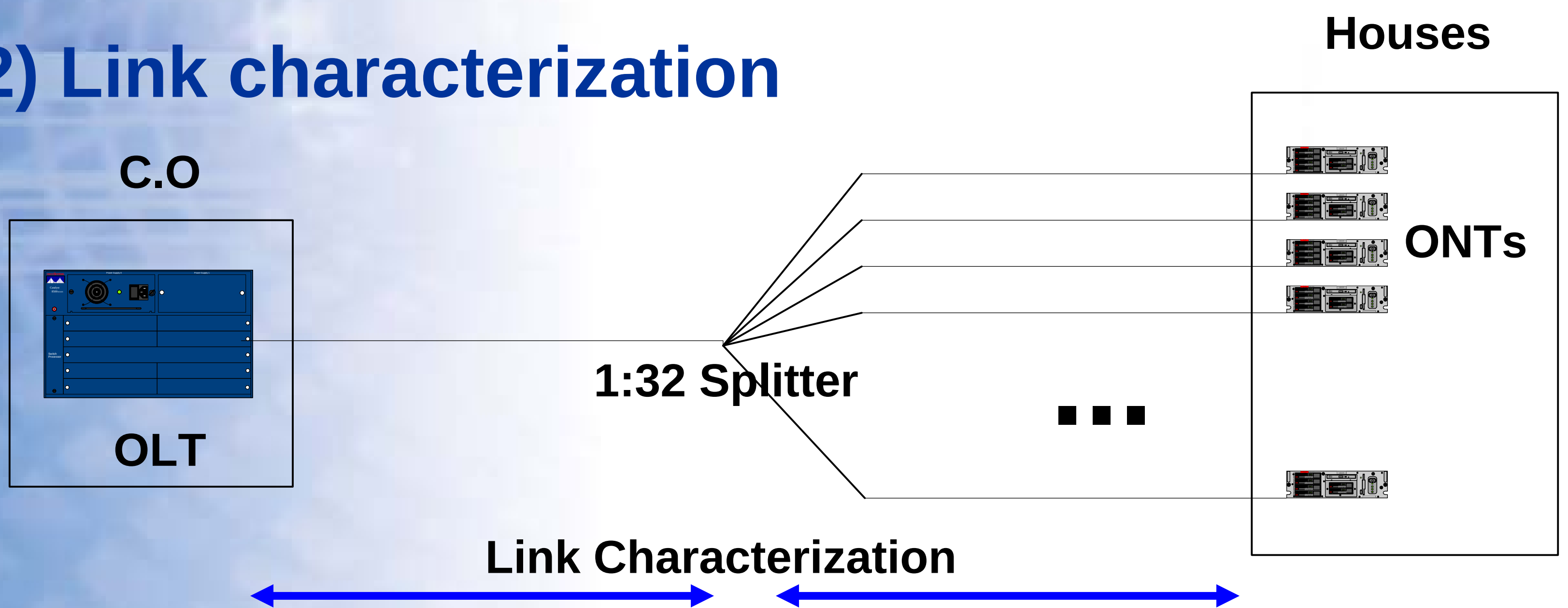
Step 4) End-to-end Loss & Back Reflection Testing

Step 5) OLT and ONTs Turn up

1) Verify total loss budget



2) Link characterization



- Done before splicing or connectorizing splitter
- From OLT towards splitter and splitter to the ONT
- Averaged loss and attenuation values through bi-directional OTDR measurement at 1310, 1490 & 1550nm
- Typical attenuation figures for new G.652C fibers ranges from:
    - 0.33 - 0.35 dB/km at 1310 nm
    - 0.21 - 0.23 dB/km at 1490 nm
    - 0.19 - 0.21 dB/km at 1550 nm

3) Coupler and Splices Characterization

Coupler and Splices Characterization

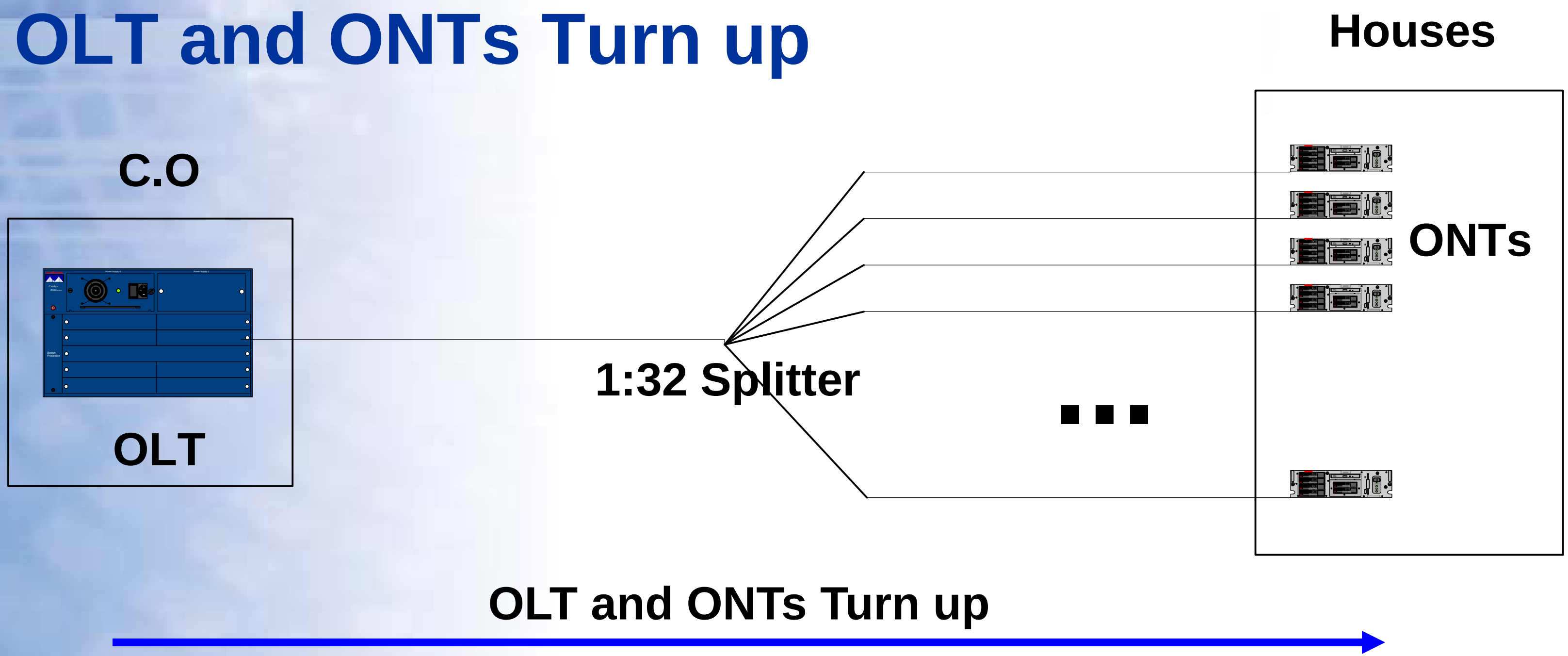
- Done after splicing or connectorizing the in-port of splitter
- From splitter output ports back to the OLT
- Loss and backreflection value at 1310, 1490 & 1550nm with OTDR combined with pulse suppressor box and bare fiber adaptor (if spliced)
- Backreflection of coupler ports should be -35 dB or better, as per ITU-T G.983.1

4) End-to-end Loss & Back Reflection Testing

End-to-end Loss & Back Reflection Testing

- Done after splicing splitter and connectorizing ONTs & OLT
- Total end-to-end loss, splices loss, connector loss, backreflection and overall reflectance levels measured at this stage
  - done by using a 1310/1490/1550 nm source and power meter
  - Maximum end-to-end loss should be below 25 dB for a Class-B PON
- Splice loss, as well as connector reflectance, can be established by testing with an OTDR from the ONT towards the OLT (again, through the use of a pulse suppressor box), and OLT → ONT.
  - Backreflection: generally speaking, a value in the -30 to -35 dB range is sufficient. Values less than -30 dB should trigger corrective action.
  - Splice losses should be below 0.1 dB

5) OLT and ONTs Turn up



- Before any ONT turn-up
- Power at the ONTs coming from the OLT should be verified at the drop point
- Through the use of a power meter that could give pass/fail (go/no-go) power reading result per transmission lambda (1310/1490/1550 nm), as per preset manufacturer OLT threshold power values.

Maintenance Stage

Interpreting ONT Outages when Only *Some* Are Out

- check the power levels at one of the closest faulty ONTs (at 1310, 1490 and 1550 nm), where two possibilities arise
  - ***No power***, meaning fiber cut between splitter and ONT
  - Power is ***strong*** and in accordance with working power thresholds, which means that it is probably the ONT hardware that is in trouble
  - Power is ***weaker*** than expected according to the power thresholds per λ at this point
    - an OTDR should not be used from the ONTs towards the coupler, since the OTDR laser power could interfere with OLT's digital and analog signals, and result in LoS for those houses
    - live fiber detectors to verify *total* power levels (power per λ not possible) at different potential macrobending points or visual fault locators should be used

Maintenance Stage

Interpreting ONT Outages when ***All*** ONTs Are Out

- Faults of this nature can usually be easily pinpointed and linked
  - Either the OLT is out of order or to a major fault has occurred on the fiber between the OLT at the central office and the splitter input port.
- Testing with an OTDR at 1550 nm through the connectorized fiber at the central office should help locate the area of the fault
- No LoS can be generated through OTDR testing, since the network is already out

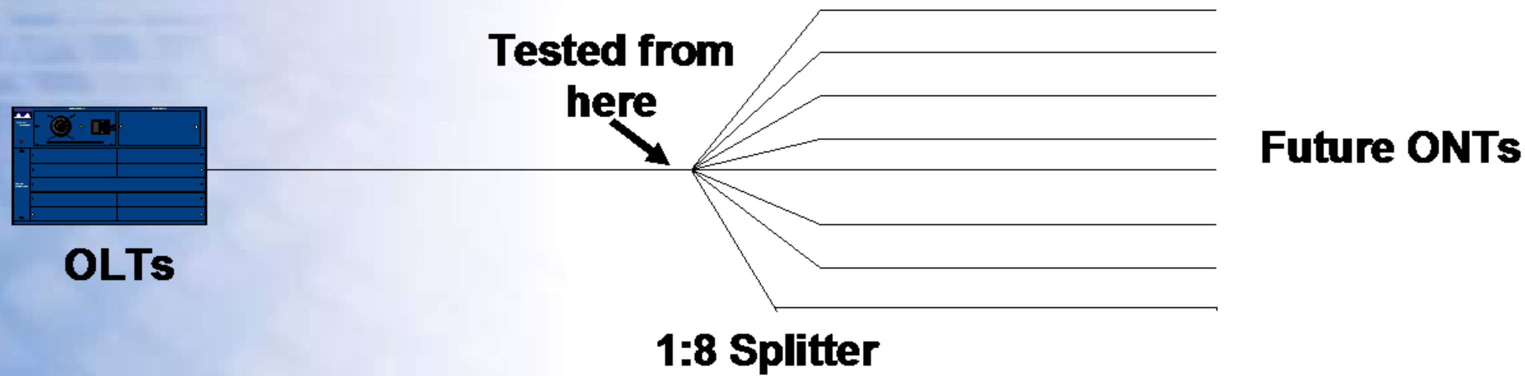
Can we test with an OTDR from the OLT ?

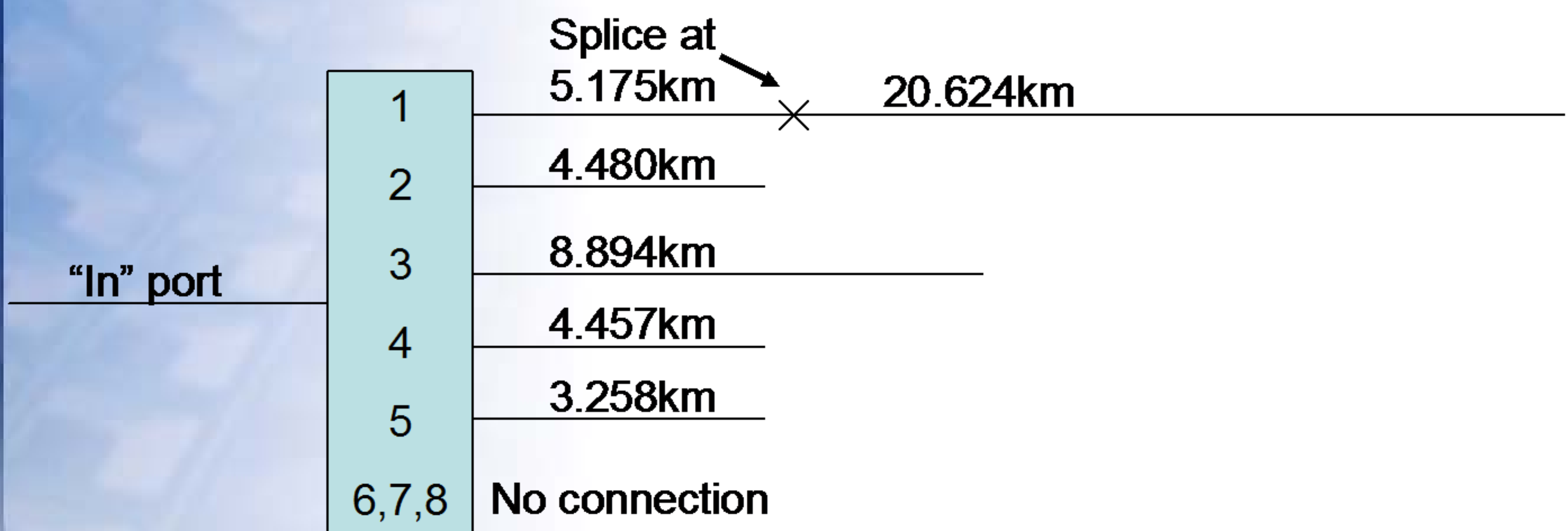
- **Application**: Saves as-built fiber-optic PON network diagram for future reference, and allows testing from the central office (instead of just form the ONTs) for:
- Connector ORL
- End-to-end
  - Loss
  - Back reflection
- Section attenuation

These tests also allow for the computing of key ***bi-directional*** information on those elements.

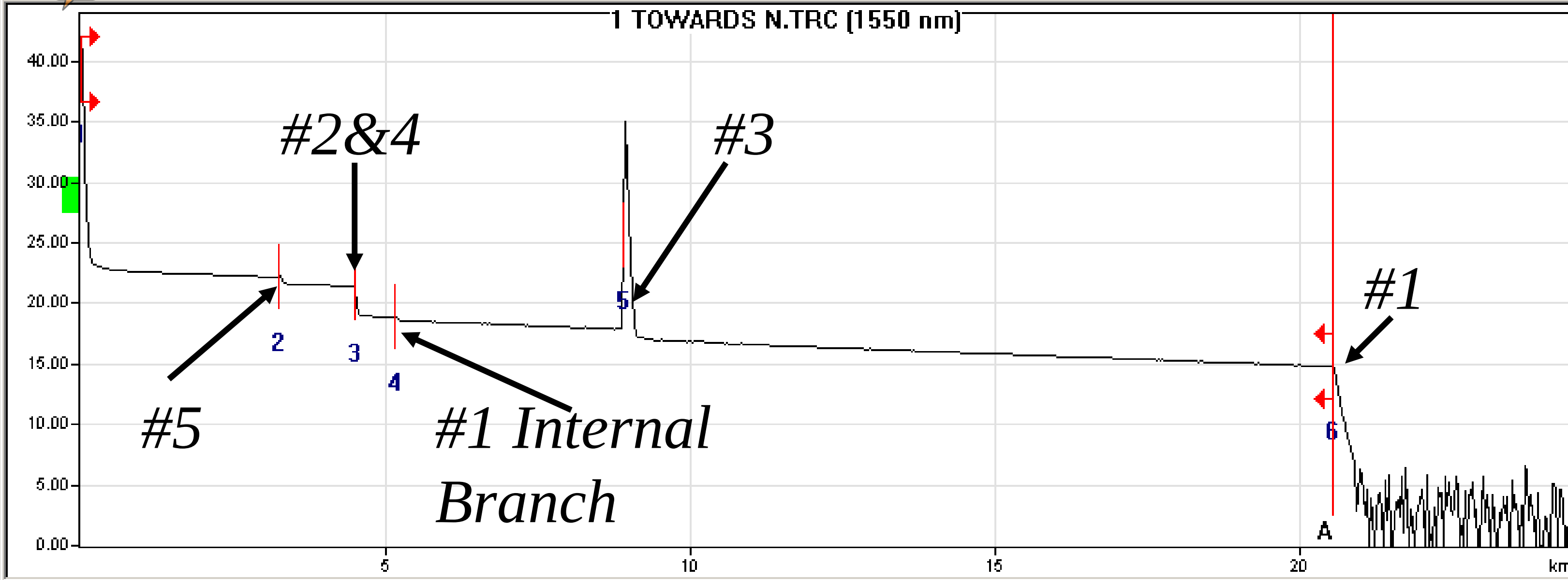
- **How** ?: through the use of a PON-tuned OTDR (Rayleigh backscattering from many spans and splitter loss)

Example #1


Tested from here
OLTs
Future ONTs
1:8 Splitter


Splice at 5.175km
20.624km
"In" port
1
2
3
4
5
6,7,8
4.480km
8.894km
4.457km
3.258km
No connection

OTDR Advanced



Event | Span | Measure | Trace Info

Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
⟼	(3.267 km)		0.751		0.230	0.751
⎍	2	3.267	0.435	-66.1		1.186
⟼	(1.235 km)		0.289		0.234	1.475
⌐	3	4.503	2.399*			3.874
⟼	(0.671 km)		0.142		0.212	4.016
⌐	4	5.174	0.224			4.240
⟼	(3.732 km)		0.747		0.200	4.987
⎍	5	8.905	0.730	>-21.9*		5.718
⟼	(11.631 km)		2.262		0.195	7.980
⎍	6	20.537	- - -	-64.1		7.980

Comments

Change

Insert

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Analyze

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Exit

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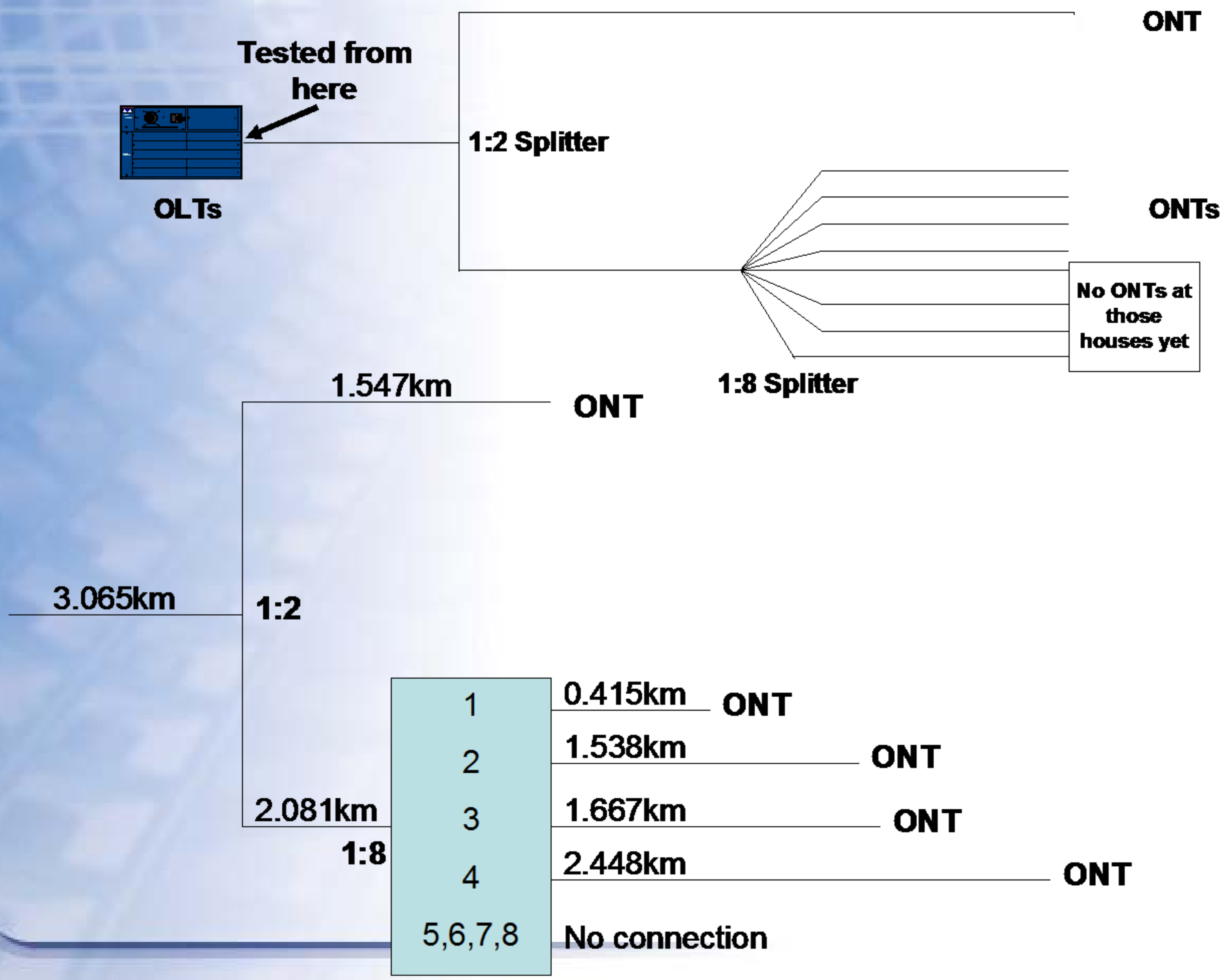
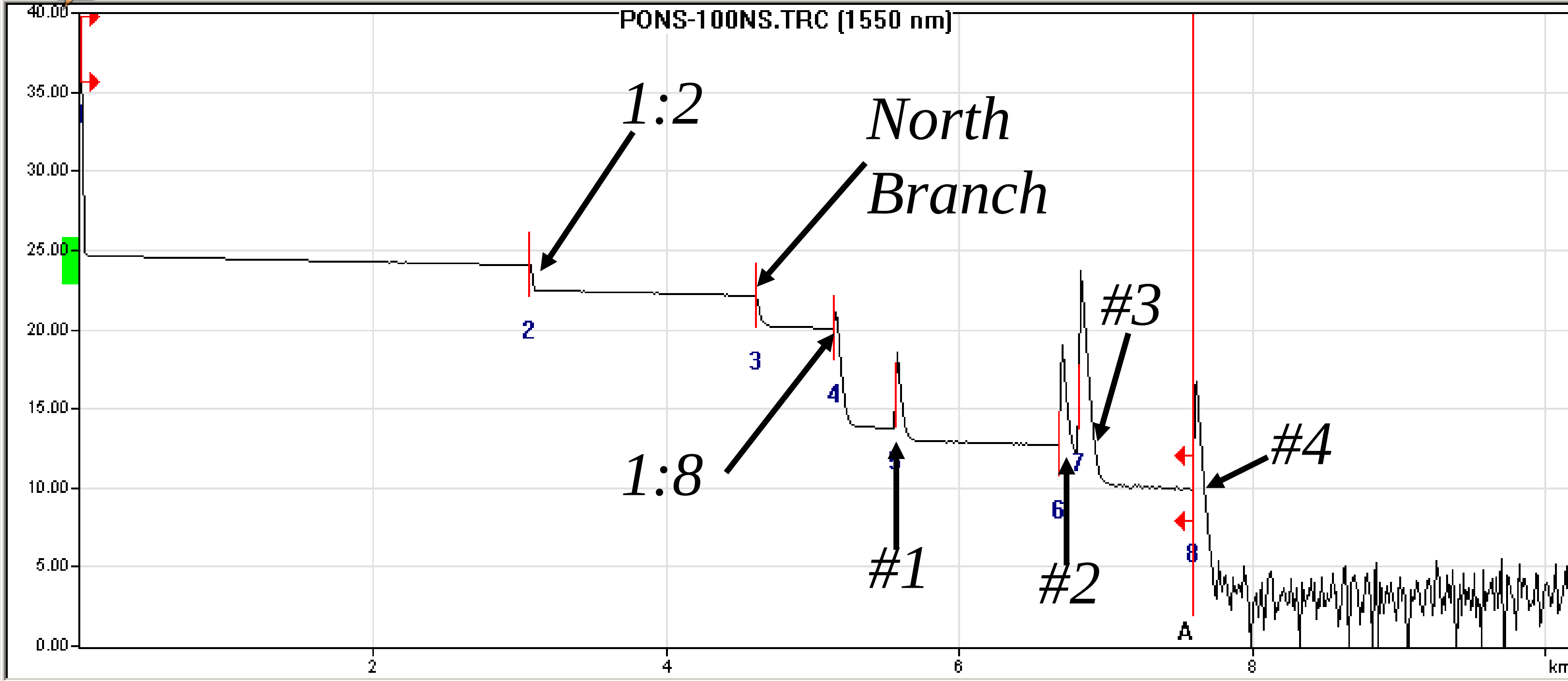
Example #2



Tested from here
OLTs
1:2 Splitter
ONT
ONTs
No ONTs at those houses yet
1:8 Splitter
1.547km
ONT
3.065km
1:2
2.081km
1:8
1
2
3
4
5,6,7,8
0.415km
ONT
1.538km
ONT
1.667km
ONT
2.448km
ONT
No connection

OTDR Advanced



Event | Span | Measure | Trace Info

Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
⟼	(0.414 km)		0.243		0.587*	10.945
⎍	5	5.560	0.692	-48.8		11.637
⟼	(1.123 km)		0.320		0.285	11.957
⎍	6	6.683	0.327	-45.3		12.284
⟼	(0.129 km)		1.405		10.880*	13.689
⎍	7	6.812	0.897	-34.3*		14.586
⟼	(0.781 km)		0.623		0.797*	15.209
⎍	8	7.593	- - -	-43.5		15.209

Comments

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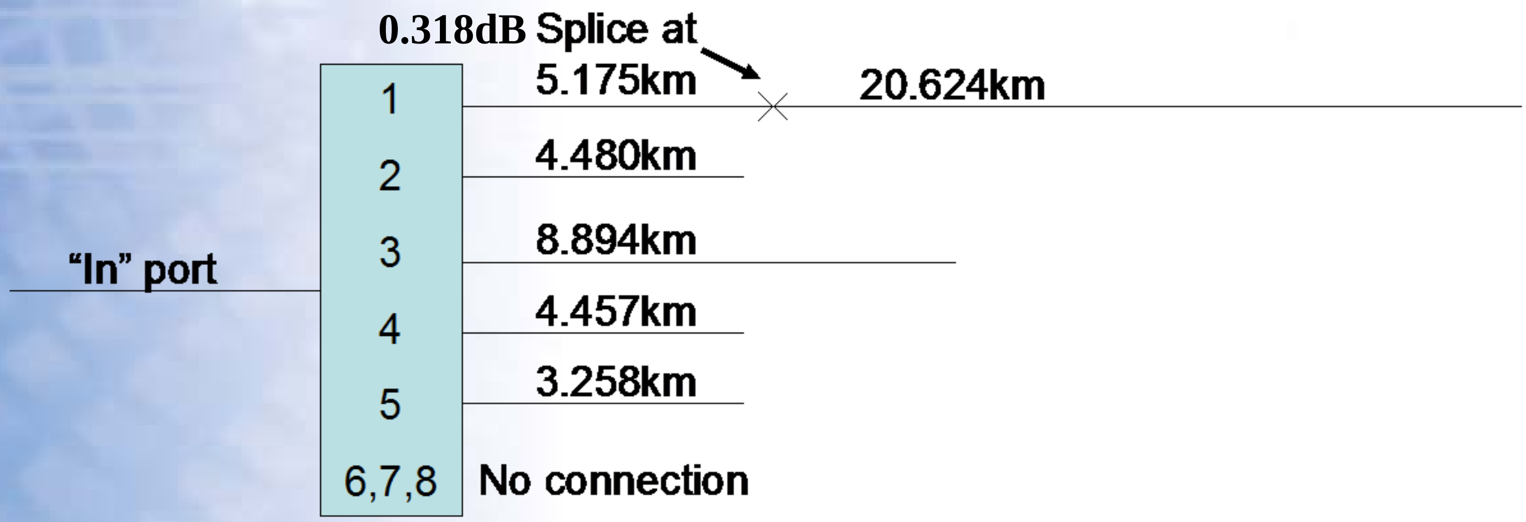
Mathematical Splice Loss Predictions for PTMPN PONs

- OTDR trace is now built from the additive contributions of Rayleigh backscattering from different fibers spans
- Apparent event losses in a PTMPN OTDR trace will be lower for the same event than in a point-to-point network
- PTMPN OTDR signature can be calculated and predicted. Each real event on an individual fiber of the network (either a splice loss or even an end-of-fiber) will show-up on the PTMPN OTDR trace as follow:

$$\text{Loss} = 5 \times \text{Log}\left[\frac{\sum_{j=1}^{N} 10^{-\text{Cumulative loss before}/5}}{\sum_{j=1}^{N} 10^{-\text{Cumulative loss after}/5}}\right]$$

Splice Loss Calculation

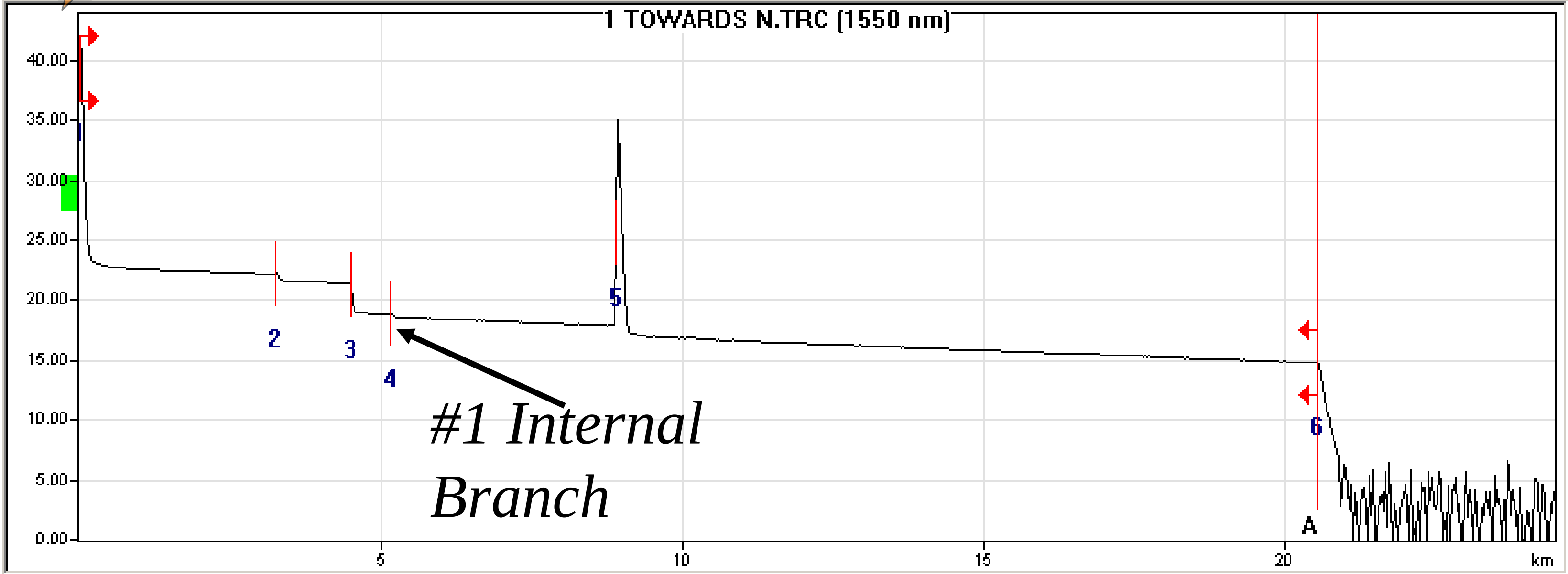


$$\text{Loss} = 5 \times \text{Log}\left[\frac{10^{-1.02\text{dB}/5} + 10^{-2.59\text{dB}/5}}{10^{-1.34\text{dB}/5} + 10^{-2.59\text{dB}/5}}\right] = \mathbf{0.21}\text{dB}$$

Where fibers 1 and 3 have a length of at least 5.175 km:

- CumLossIn1: 1.02 dB, CumLossOut1: 1.34 dB
- CumLossIn3: 2.59 dB, CumLossOut3: 2.59 dB

OTDR Advanced



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Change | Insert | Delete | Analyze | Comments

Quick Save | Storage | Report | Setup | Quick Print | Help | Exit

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Conclusion

- FTTH networks using PON technology can be characterized and maintained every step of the way
- Through the use of very simple actual and new fiber-optic test and measurement equipment.
- OTDRs can be used quite easily not only from the ONTs towards the coupler and OLT at the central office, but also, as demonstrated, from the OLT towards the PTMPN.
- For that type of network architecture (for PONs in PTMPN), mathematical splice loss predictions have been demonstrated to be accurate and, consequently, can help you properly characterize your networks