

# **Optical Network Terminals (ONTs):**

## ***Lightning Damage and Standards - What's the Latest Information?***

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**(Presented by Tim Ardley)**

# Topics

- What are ONT's?
- What do they look like.
- Installation topology and diagrams.
- Typical types of Lightning damage.
- Facts about damage.
- Quick "why".
- What was learned.
- Conclusion.

# What Are ONT's?

## Optical Network Terminal

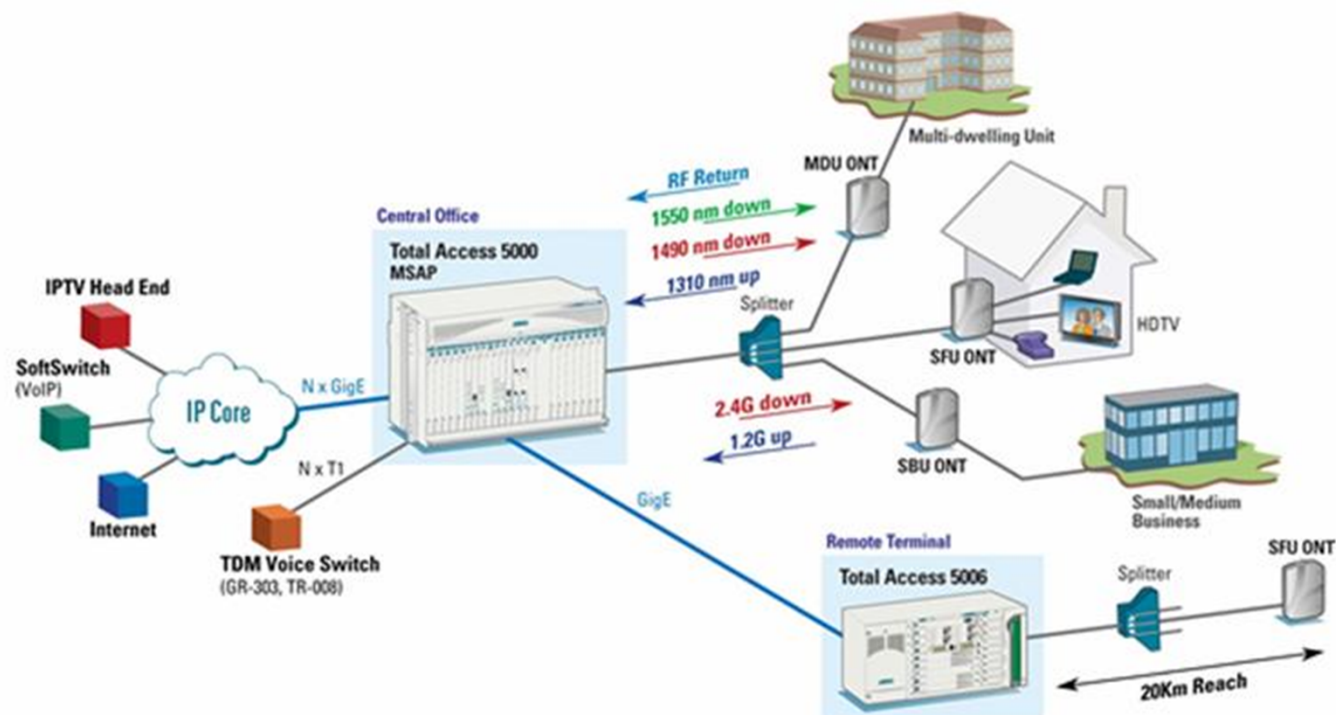
- **Optically fed from the telecommunications network.**
- **Provides Video, Data, and POTS to residences and small businesses.**
- **Typical customer interfaces Ethernet, POTS, and possibly coax.**
- **Typically powered by 12 V DC from a rectifier/UPS/battery backup at the customers location and powered by customers 120 V AC.**
- **Typically has alarm leads connected to the UPS/battery backup in case of failure.**

# What do they look like?

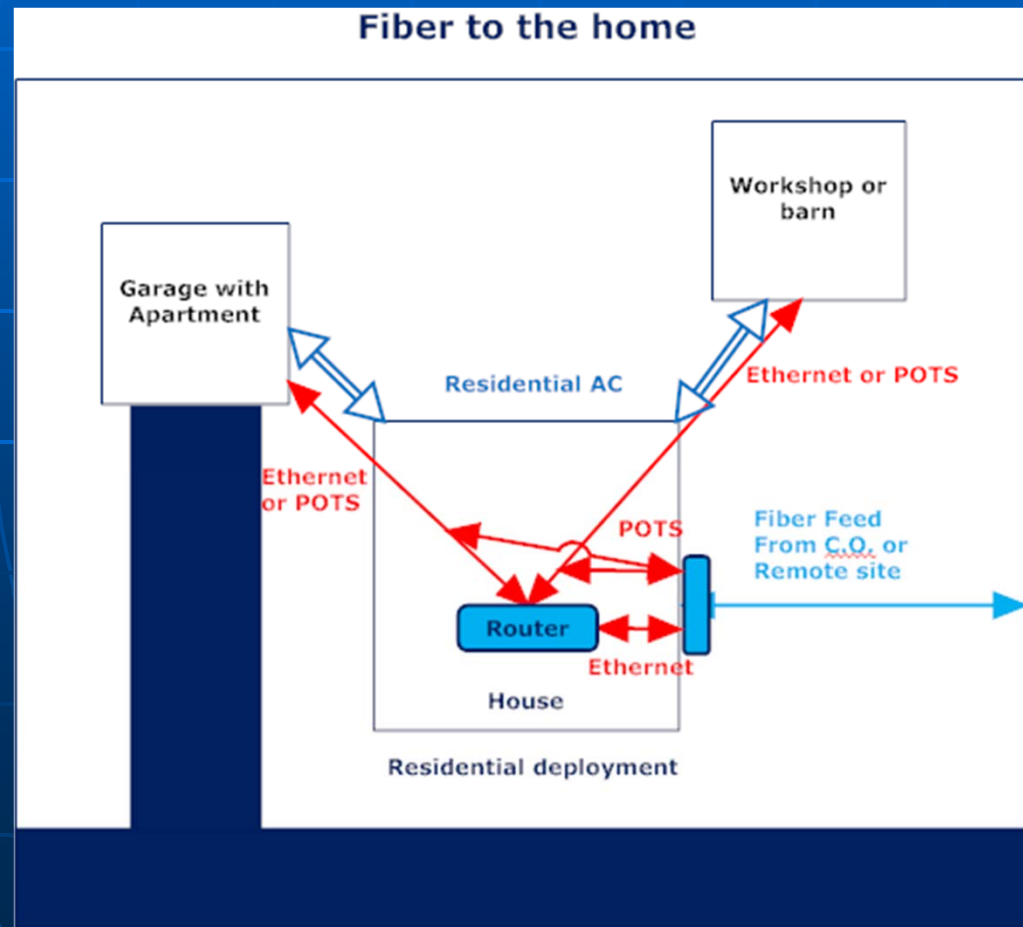


# What Does a Typical ONT Installation Topology Look Like

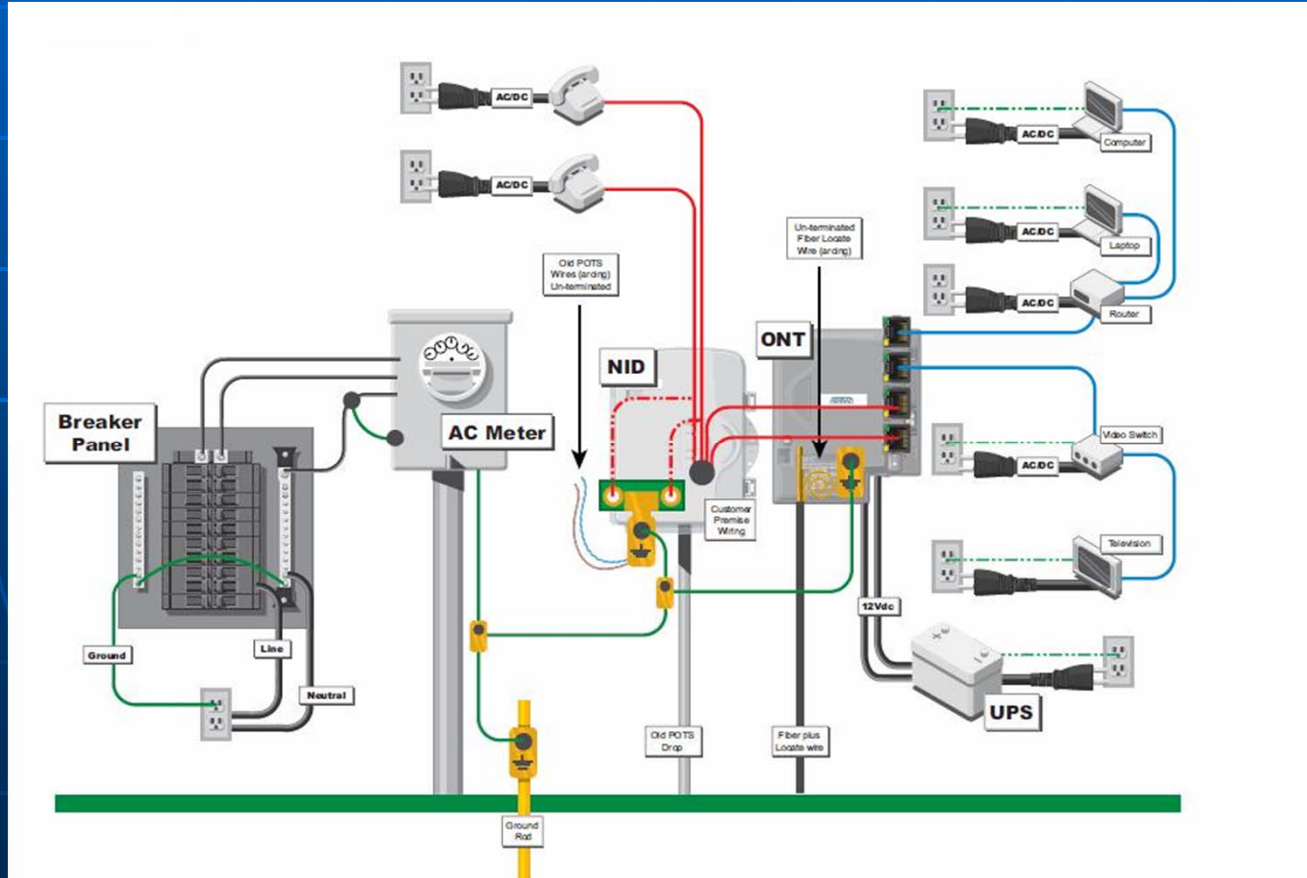
## GPON from the Total Access 5000/5006



# What Does a Typical ONT Installation Topology Look Like

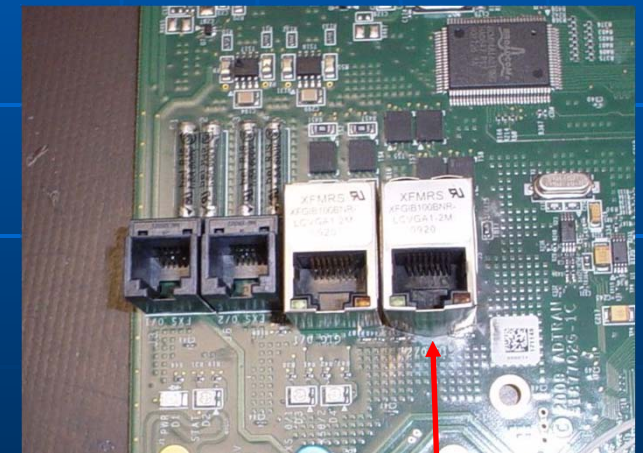
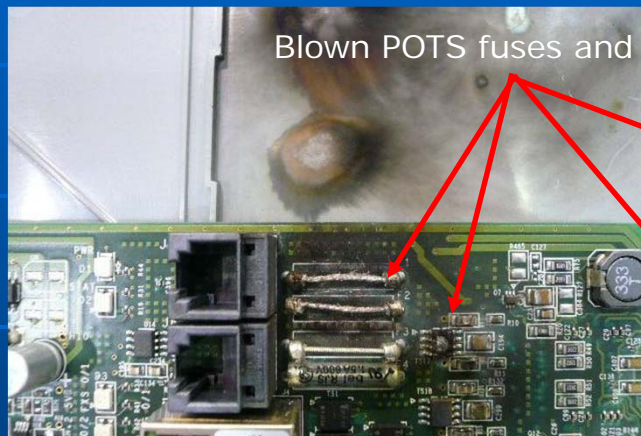


# What Does a Typical ONT Installation Look Like





# Typical Lightning Damage





# Facts

- **The Severity of the Damage – component damage far exceeded what would be expected even on OSP interfaces from lightning and power fault tests in GR-1089-CORE.**
- **Type of damage – POTS protection IC's, Ethernet jacks/circuits, RJ11's, frame ground traces.**
- **Circumstances – storm related.**
- **Geography – no significant correlation to geography.**
- **Similar types of damage reported across all ONT Vendors.**
- **Damage NOT limited to a specific vendor or service provider.**
- **Damage NOT limited to United States.**
- **International problem, Japan NTT major ongoing investigation and ITU-T contributions.**

# Why?

**Last years ONT presentation has a lot of information.**

- Lightning related Ground Potential Rise (LGPR)**
- Improper Bonding and Grounding.**
- Improper treatment of abandoned copper.**
- Improper treatment of fiber shield / locate wire.**
- Grounded TVS protectors on Ethernet interfaces.**
  - i.e. from power strips, and data surge protectors.**
- The type of Battery Backup Unit (BBU).**
  - i.e. grounded 3 prong vs. 2 prong.**

# From Hypotheses to Validation

- **ADTRAN made several ONT circuit modifications over the past couple years as new information was learned.**
- **ONT storm damaged returns were analyzed and data collected.**
- **Training material for mitigating ONT damage using good installation practices, and an ONT white paper were provided to ADTRAN customers and engineering firms.**
- **Return Data comparisons of initial designs versus each step improvement were conducted.**

# What was Learned

- **Good installation practices and the white paper seem to have had a significant effect.**
  - **Most obvious example is that the rate of catastrophic damage dropping significantly with service providers who received installation training. Particularly the treatment of the fiber locate wire or shield.**
- **POTS: Ethernet damage is typically 5:1 ratio.**

# What was Learned

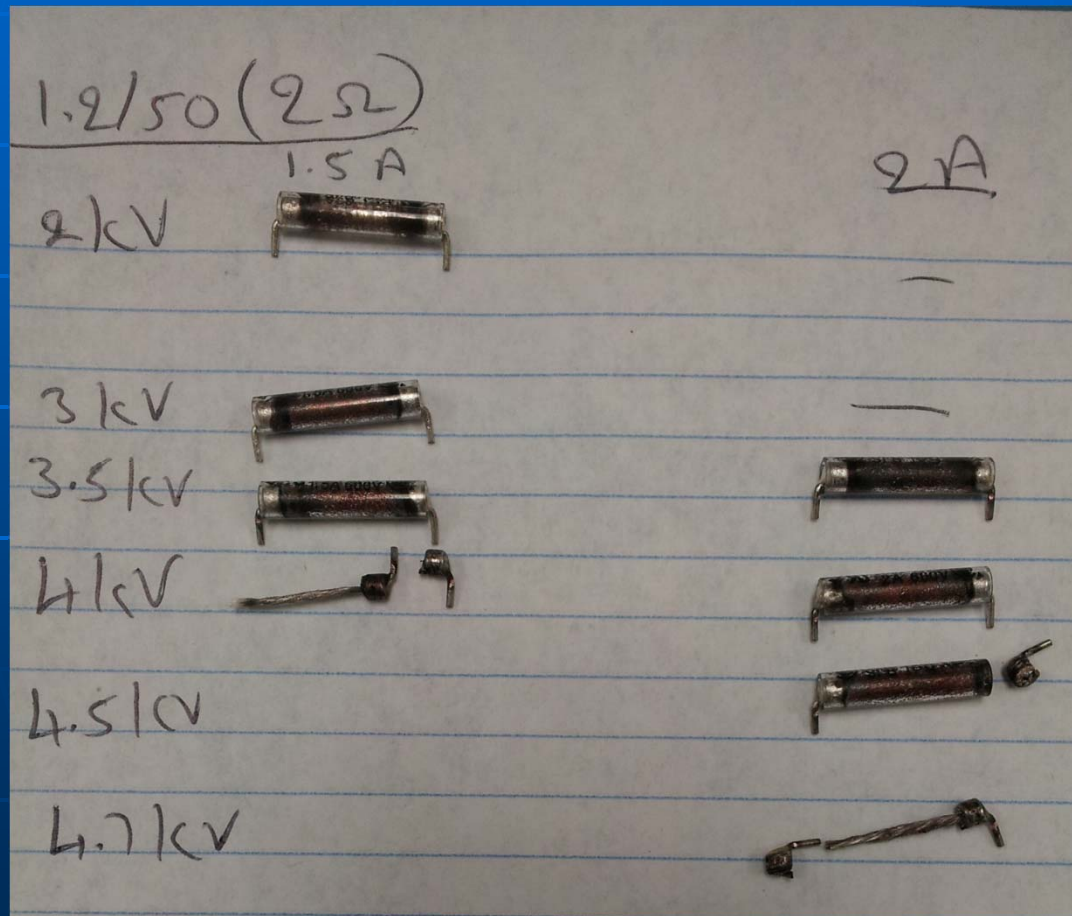
- **A surprise we found was that transients were affecting alarm and DC leads between the BBU and the ONT (can be up to 150 feet) and can kill the processor or ONT power supply. Suspect it is coupling affects as these are often run next to ground wires, and AC wiring.**
- **Protection is needed on these alarm I/O's to the processor and 12 V DC input!!!**



# What was Learned for POTS

- **POTS damage has dropped significantly after implementing the lightning protection level now required by GR-1089-CORE issue 6.**
  - **Battery tracking SLIC protection IC's were used to limit over stress on the SLIC.**
  - **Improved gate reference circuitry compared to the recommendation from the manufacturer.**
    - **This improvement was seen in the lab, but difficult to quantify in field units.**

# Fuse Characteristics



- Lab analysis points to some surges seen are in the 4 kV to 5 kV 1.2/50 range.
  - Glass case breaking at 4 kV for 1.5A fuse.

# What was Learned for Ethernet

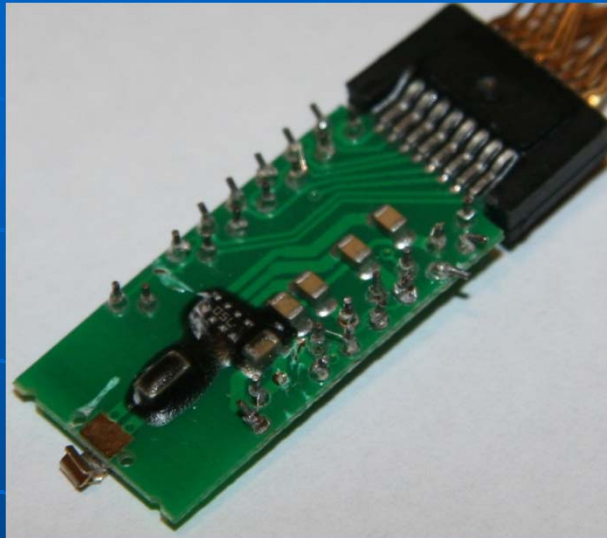
- **Areas that substantially mitigated damage**
  - **Increasing isolation to over 6 kV.**
    - Using discrete transformers instead of integrated magnetics jacks.
  - **Eliminating “Smith type” terminations where possible.**
  - **For Smith type terminations:-**
    - Use equivalent of 6 kV HV caps in terminations.
    - Matching the wattage of the resistors to the HV capacitors.
  - **Using 27 A 8/20 us rated tertiary protection.**
    - 270% increase from old design.
  - **Increasing spacing NET attributes.**
    - Watch out for JACK connector spacing's too.
  - **Training to have customers remove data protectors on Ethernet circuits.**

# Integrated Jacks

## ■ Areas of consideration

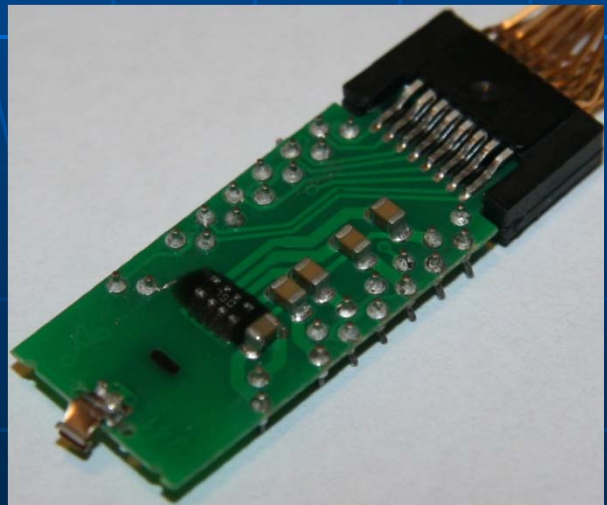
- There has been cases where they don't meet 1500 V RMS isolation.
- There has been instances of a dual integrated socket where all the Bob Smith resistors share a single 2kV capacitor.
  - This is not shown on their data sheet schematics.
- Traces are sometimes too small and fail open during the metallic lightning tests or fail the 120 V 25 A power fault (line simulator criteria).
- Shielded units not meeting isolation to the shield.
  - The PCB pin ring reduces the distances.
- LED options not meeting isolation to the Ethernet pins.

# Integrated Jacks



**Common to see chip resistor arrays that fail during longitudinal surges.**

**Sockets sharing a single high voltage Bob Smith capacitor to ground and therefore no isolation between ports.  
(Picture shows a PoE solution).**



**Sealing the Smith components to try and combat isolation breakdown.**



# Codes and Practices

**RUS** - RUS Bulletin 1753F-153, RUS Form 515d draft 4/12/11, Specifications and Drawings for Service Installation at Customer Access Locations.

Updated to include ONT installation guidelines. Permits grounding or not grounding the fiber locate wire and ONT ground based on the NEC. It discusses virtually nothing that helps mitigate damage.

**NEC** – new Article 840 that covers ONT's.

Essentially states that ONT's must be grounded if required by the NRTL Listing. Requirements in UL 60950-1 essentially would require grounding due to POTS TVS devices, so in a round about manner ONT's must be grounded.

# Codes and Practices

## **UL-60950-1 (safety Listing)**

Requirements in UL 60950-1 essentially would require grounding due to POTS TVS devices, so in a round about manner ONT's must be grounded per the NEC, and RUS.

## **GR-1089-CORE issue 6**

Updated last year to improve reliability (added 1 kV 100 A 10x1000) but still deficient in terms of the voltage as it only tests to 1.5 kV. Needs 5 kV or higher test as was proposed but deferred. ITU-T appears to be going much higher!

# Codes and Practices

## NEC in detail regarding the fiber locate wire

The NEC permits the methods described below, however it does not allow the floating of the locate wire inside the ONT. We found that keeping the locate wire far from the ONT is very effective!. Note that article 770.100 only dictates grounding methods if the "grounding option" of 770.93 is chosen.

### ***770.93 Grounding or Interruption of Non–Current-Carrying Metallic Members of Optical Fiber Cables.***

***Optical fiber cables entering the building or terminating on the outside of the building shall comply with 770.93(A) or (B).***

*(A) Entering Buildings. In installations where an optical fiber cable is exposed to contact with electric light or power conductors and the cable enters the building, the non–current-carrying metallic members shall be either grounded as specified in 770.100, or interrupted by an insulating joint or equivalent device. The grounding or interruption shall be as close as practicable to the point of entrance.*

# Codes and Practices

## NEC in detail regarding the fiber locate wire

*(B) Terminating On the Outside of Buildings. In installations where an optical fiber cable is exposed to contact with electric light or power conductors and the cable is terminated on the outside of the building, the non-current-carrying metallic members shall be either grounded as specified in 770.100, or interrupted by an insulating joint or equivalent device. The grounding or interruption shall be as close as practicable to the point of termination of the cable.*

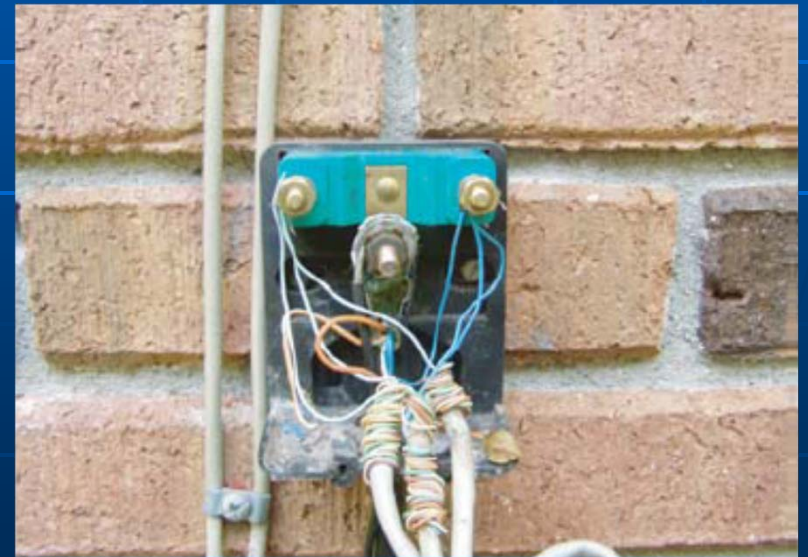
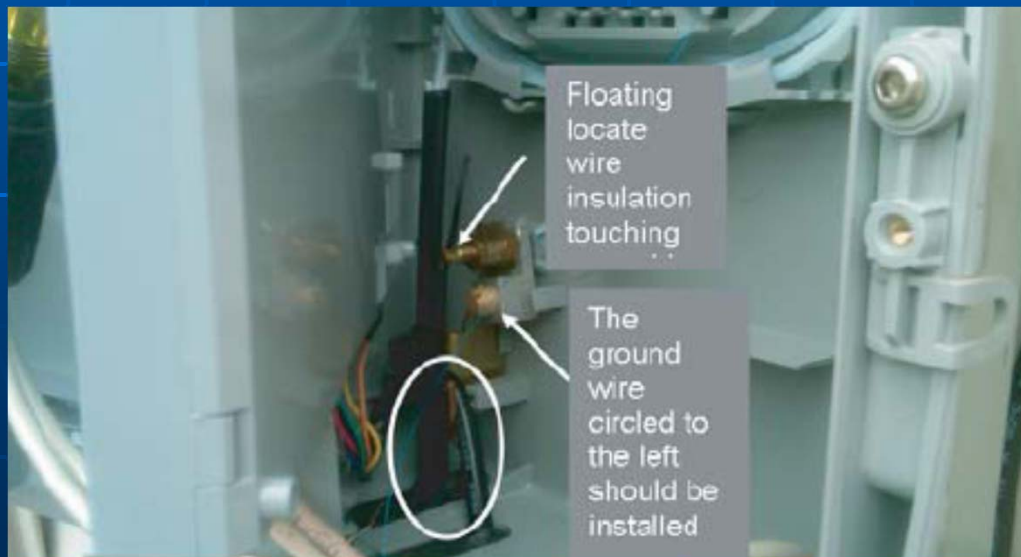
*IV Grounding Methods.*

**770.100** *Entrance Cable Grounding.*

**Where grounded**, the non-current-carrying metallic members of optical fiber cables entering buildings shall be grounded as specified in 770.100(A) through (D).

# Field Deployment Issues

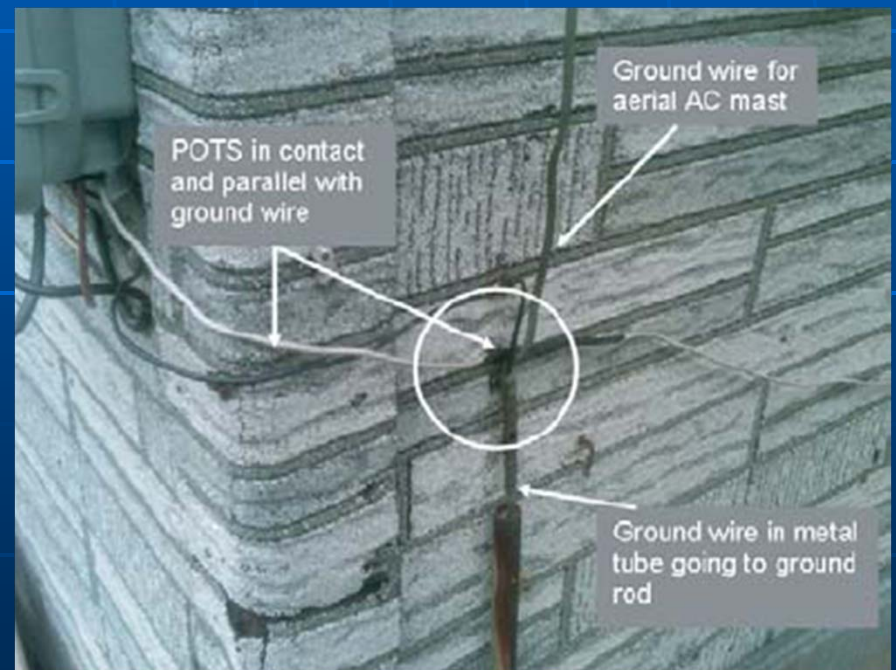
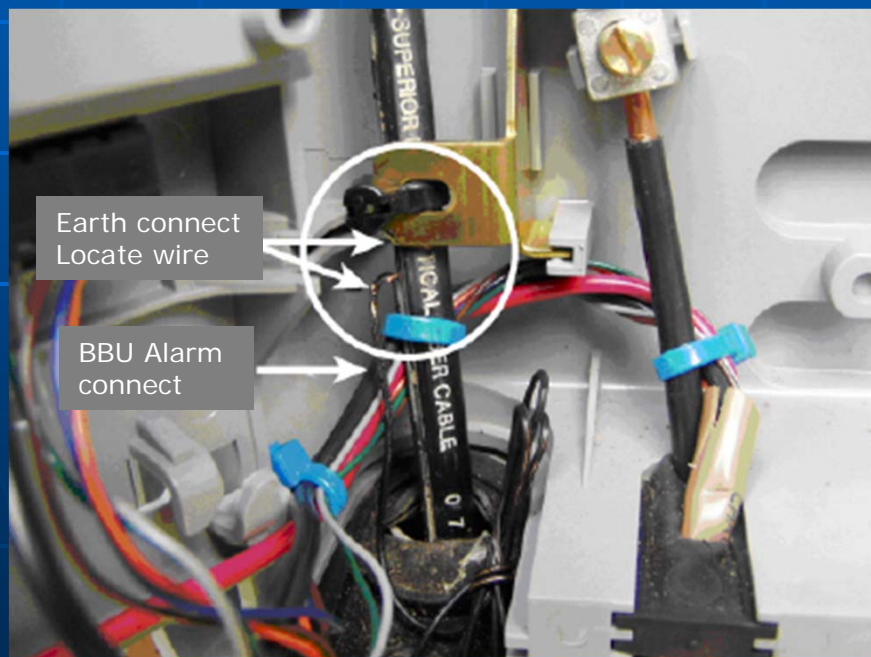
**Never assume things are done correctly**





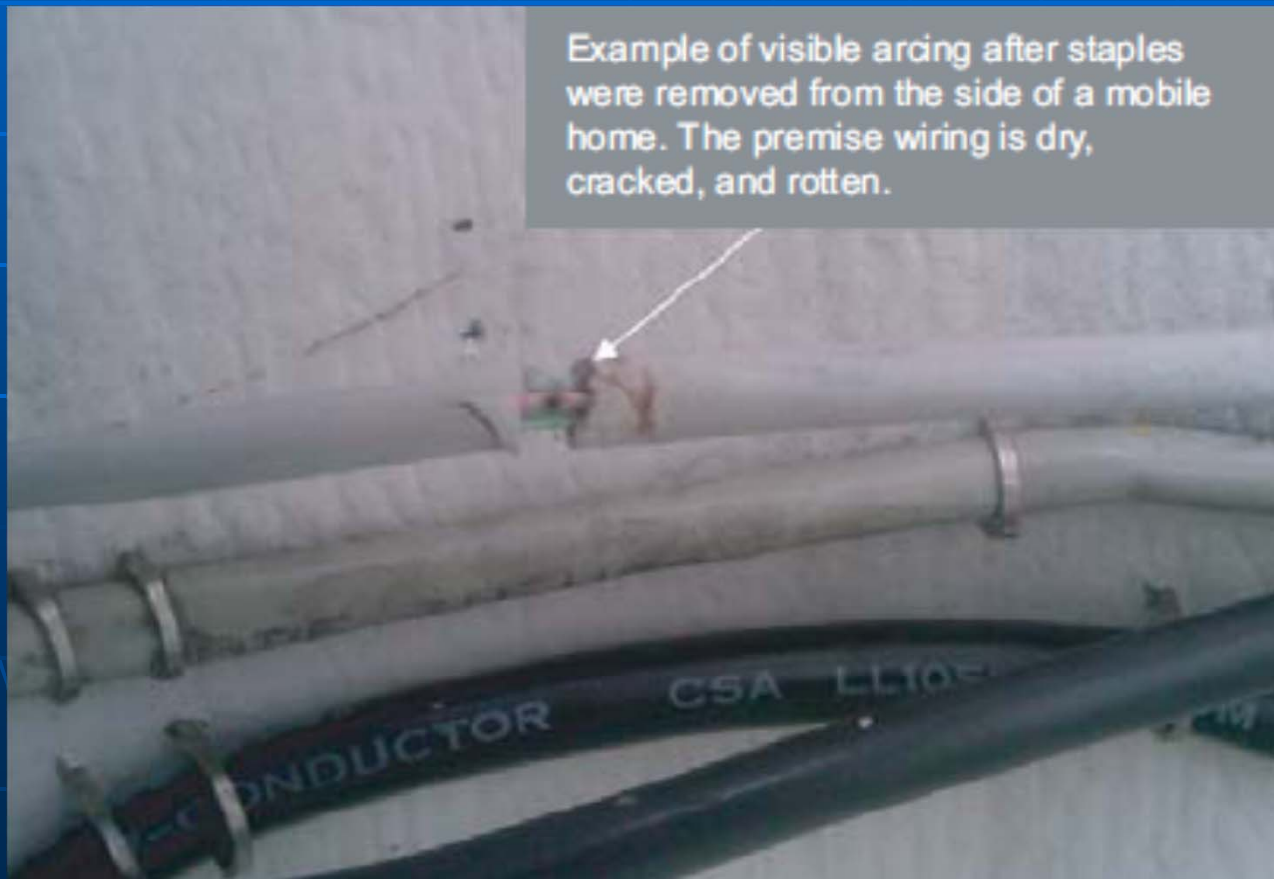
# Field Deployment Issues

**Never assume you have asked all the correct questions.**



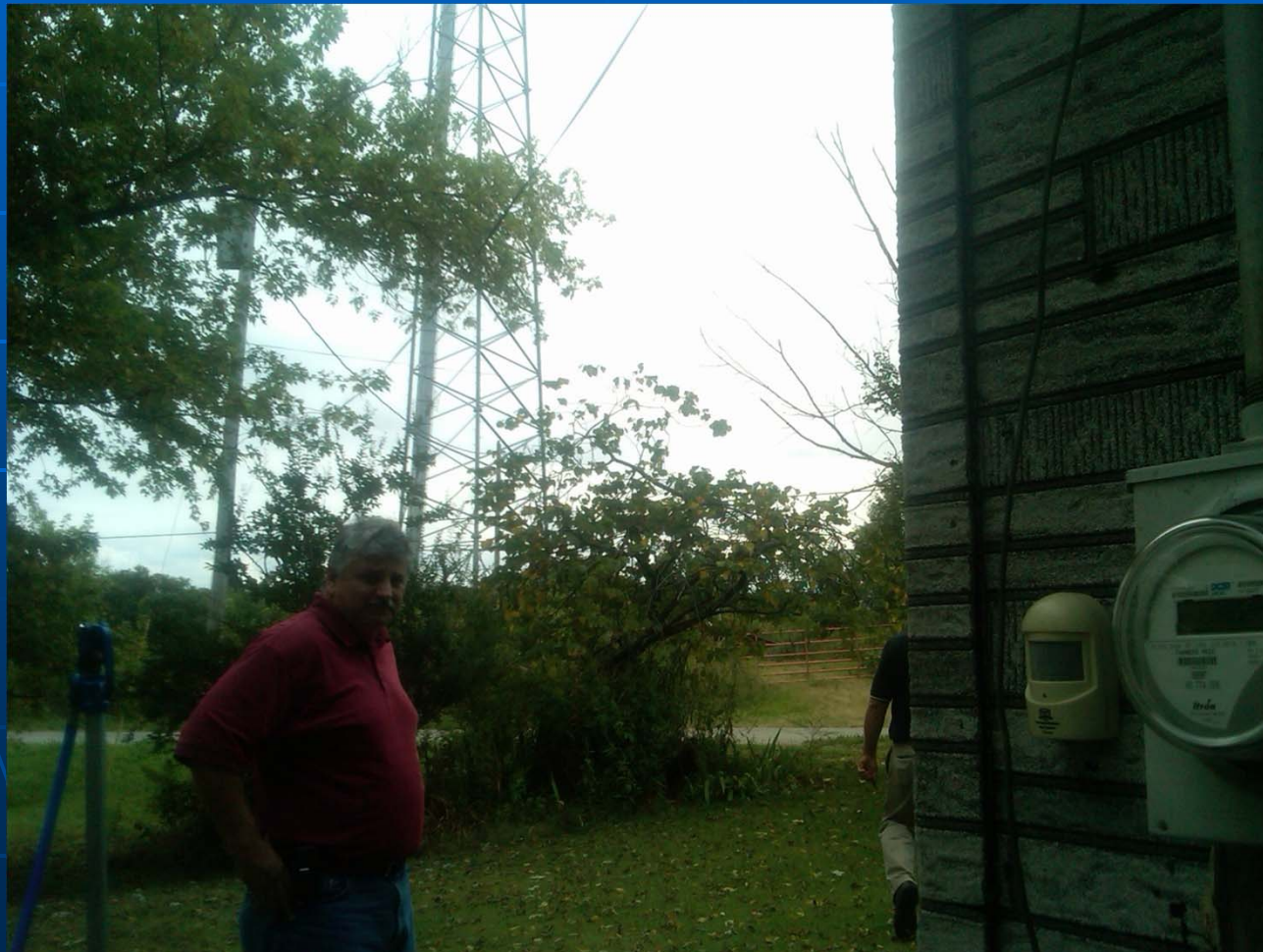
# Field Deployment Issues

**You cannot protect from mistakes made by contractors.**



# Field Deployment Issues

**You cannot protect the un-protectable!**





# Field Deployment Issues

**You cannot protect cows or golf greens either!**



When the current starts to spread when a cow is eating grass, the current flows from the cow's mouth (A), goes through its leg (B), and goes back to the ground. The current will flow until the voltage becomes zero.



Because cow's hind leg (D) has lower potential energy than its front leg (C), the current can flow through the cow. The cow becomes a part of electric circuit.

Then the cow gets a big electric shock and it usually dies.



# Conclusions

- 1.) Protection of ONT's requires a multi-faceted approach that includes designing for reliability AND reality, beefed up component protection and Ethernet isolation, improved lightning test requirements, following codes, adequate installation practices, Service provider training, and service provider oversight and audits of contractors work.
- 2.) Grounding of ONT's per code approved methods is required.
- 3.) GPR's are a real threat, and are the biggest root cause of ONT damage.
- 4.) Fiber locate wires (just like traditional T/R wiring) can carry extremely large lightning currents or generate in excess of 30 kV, and should never be brought into or near the ONT or its associated wiring, or connected to the ground system. Use the isolation method per the code.



# Conclusions

- 5.) Ethernet isolation may need to be 5 kV or greater. (NOT added in issue 6 of GR-1089-CORE).
- 6.) POTS protection needs to be able to handle at least a 10x1000 100 A per conductor lightning surge. (added to issue 6 of GR-1089-CORE, but voltage is too low, only 1 kV)
- 7.) Some damage is unavoidable due to location, or factors outside the service providers control.
- 8.) Repeat offenders need to be investigated for potential factors that make the ONT susceptible.
- 9.) Encourage/educate end customers to not install UPS's or AC surge strips that have the POTS or Ethernet port equipment protected from the UPS or AC surge strip.

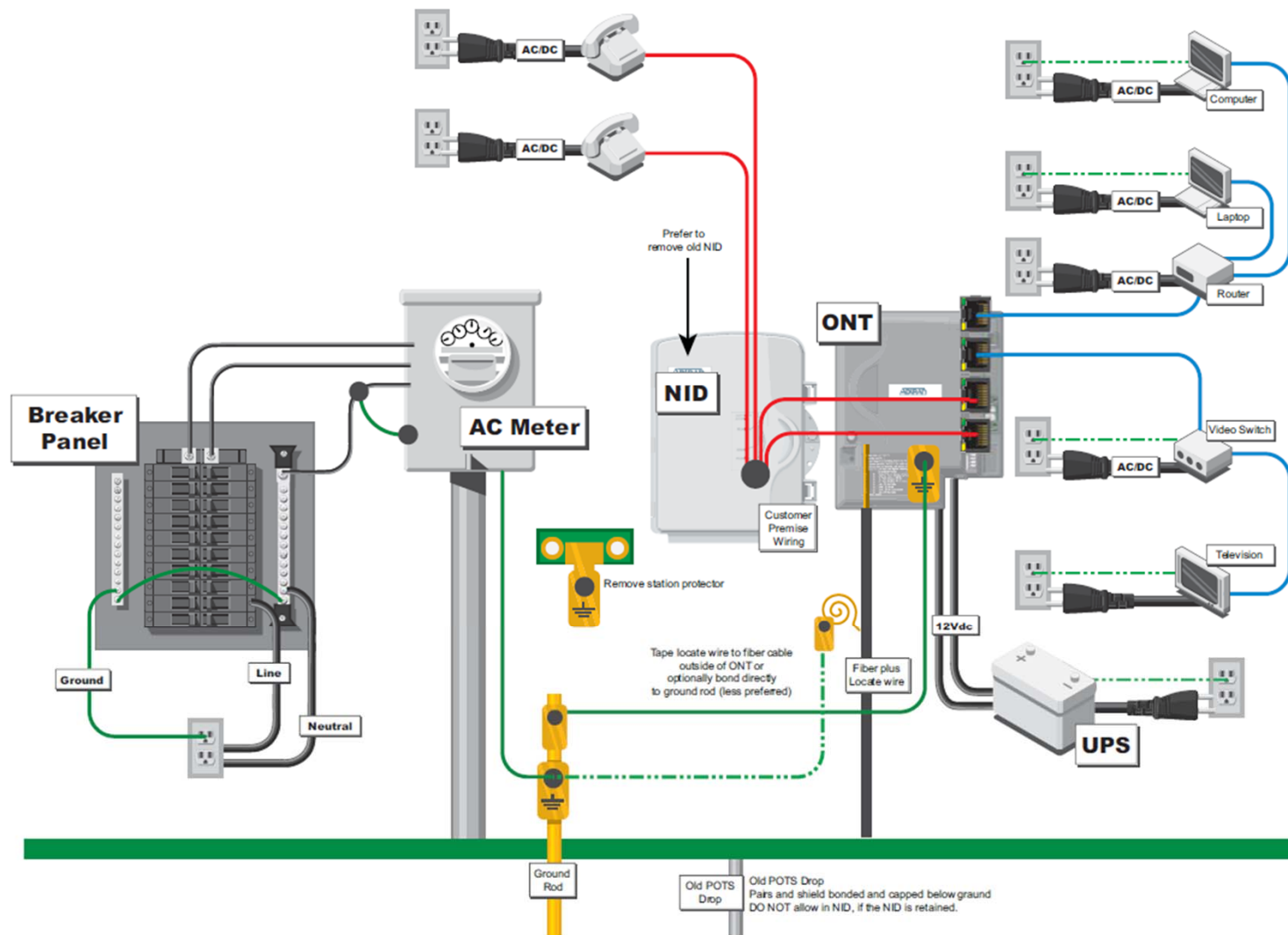
# Conclusions

- 10.) Never cross-connect the POTS or Ethernet in the old NID. Do not connect to the old station protector to the ONT customer ports, and never keep the old POTS drop connected to customer wiring.
- 11.) Inspect customers wiring (especially if outdoors) for risk factors such as stapling to metal structures, aluminum siding, mobile homes, etc. Look for parallel and close proximity of POTS or Ethernet wiring relative to the wiring to the AC mains or air conditioning units, that can induce a surge into the customer wiring.

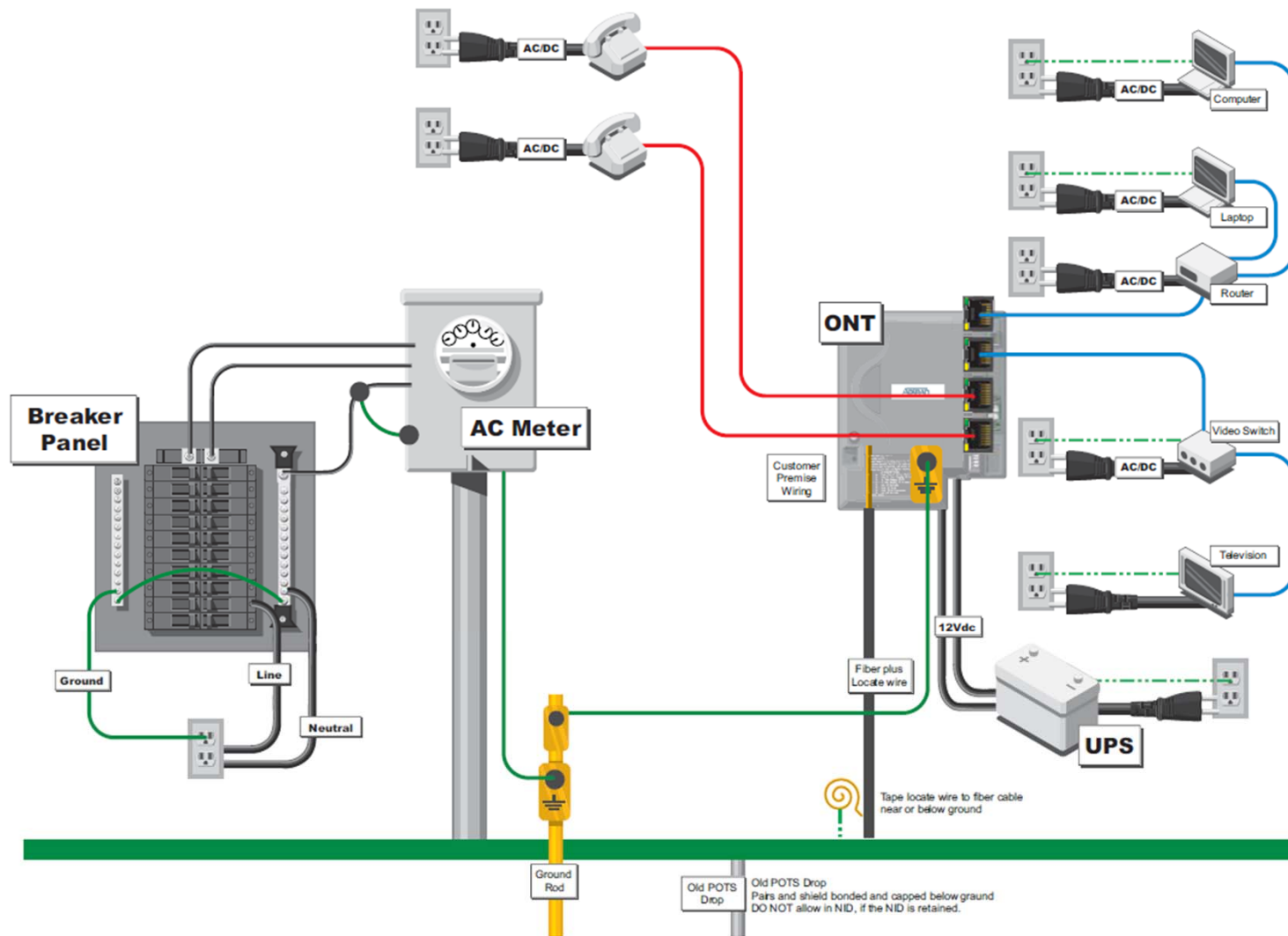
# Conclusions

- 12.) Just because an ONT is grounded and bonded per codes, don't assume it is protected from lightning. The code is mostly concerned with 60 Hz events and does not address high frequency issues. Think in terms of lightning!!!!
- 13.) Ground the ONT directly to a ground rod, not other ground wires from the meter box or old NID. These other paths can develop a voltage drop in the wiring causing damage to the POTS port or sensitive ONT electronics from a sharp ground rise.
- 14.) Three prong surge protectors for the ONT UPS has anecdotally been beneficial. The jury is still out.

# Good Installation Topology



# Best Installation Topology



# Questions