



## **Fiber Networks Around the World and A Proposal for Africa**

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## **Existing Fiber Network Examples**

- **North America**
- **California**
- **Global Undersea Routes**
- **Europe**
- **Sweden (and Vicinity)**
- **Asia-Pacific**
- **South Korea**
- **Major US carrier 1**
- **Major US carrier 2**
- **Southern and Northern Africa Undersea Routes**

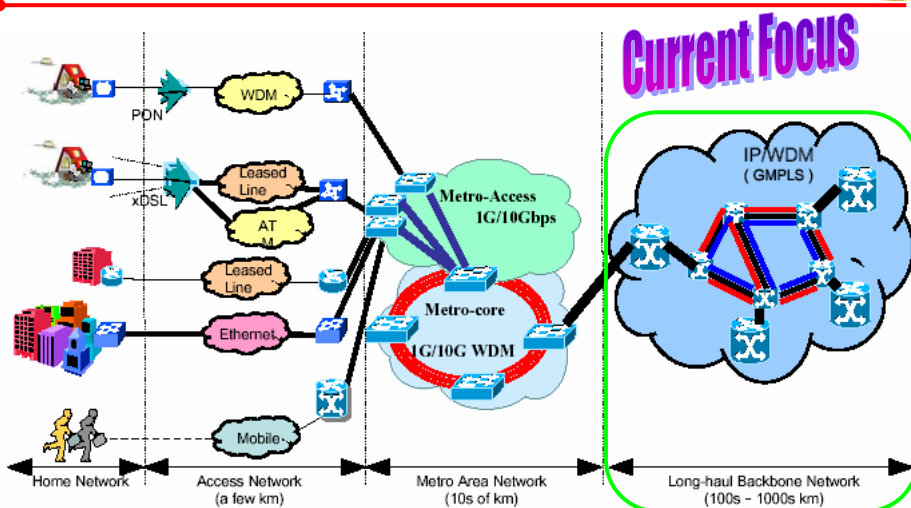
# Virtualization: Network Embedding



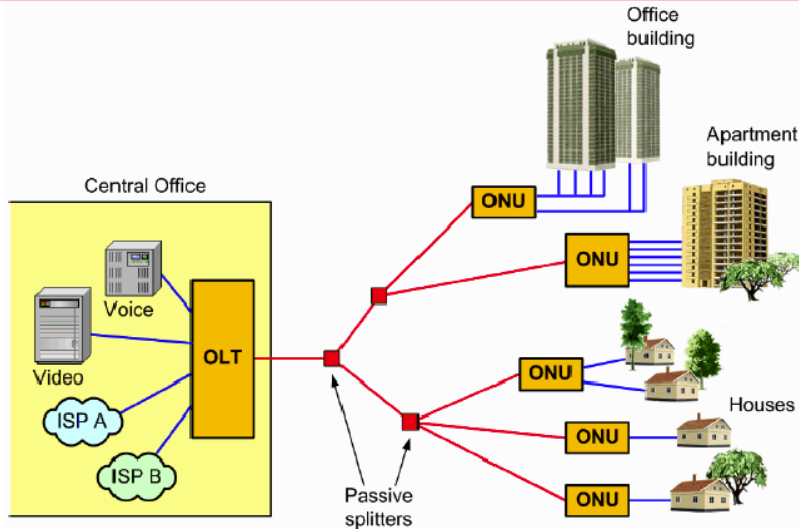
## Note:

- Fiber laid in bundles.
- Example: 864 strands/bundle, 10 bundles/conduit.
- A pair of fiber strands in a bundle can be spliced (serially and recursively) with a pair in an adjacent bundle to create a (logical) fiber link, with switching/routing equipment at either end of the link.
- A collection of such optical links – connected by switches/routers – forms a virtual topology, e.g., an IP network topology.
- A network failure, e.g., a fiber cut, can lead to a huge amount of data loss.
- Intelligent software architecture needed for diversified routing of “working” and “backup” paths.

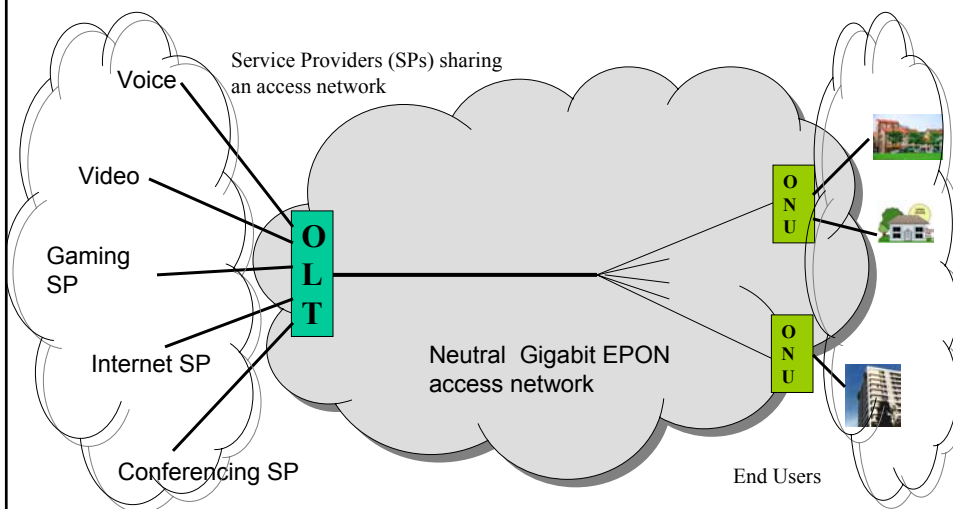
# Telecom Network Hierarchy



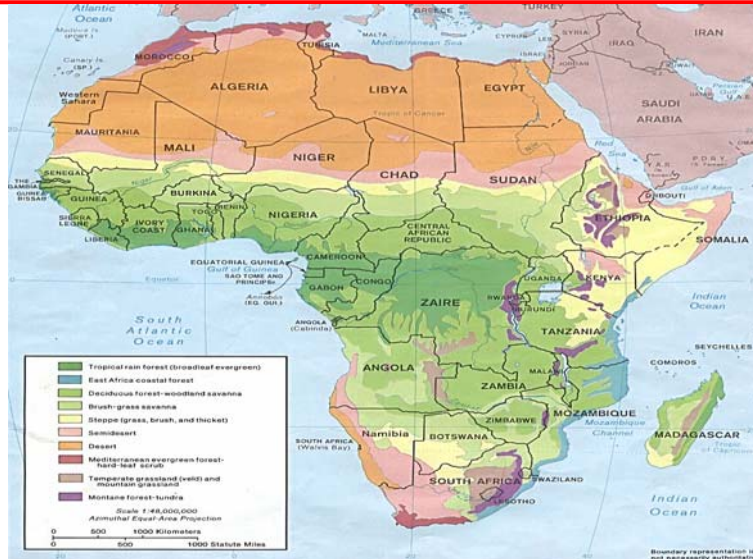
# An Access Network (PON)



# Access Network: "Open Access" Illustration



# Nature/Vegetation Map of Africa



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# Design Principles for Two-Ring Optical Fiber Network for Africa



1. Capitals and main cities as networks nodes.
2. "Outer Ring" along Africa coast.
3. "Inner Ring" through Capitals in Africa inland.
4. Bridge links connecting the two rings.

**Major objective: Fast fault recovery.**

5. Northern Africa is Desert Area... not suitable to lay fiber. So Bridge Links will bypass the Desert Area.
6. Another fiber run along Northern Africa coast will provide alternate route.

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## Need for Fault Management



- FIT (Failure in Time): # of failures in  $10^9$  hrs.
- Failure frequencies:
  - Fiber: 11,000 FIT per 10 km of fiber (~ once every 11.85 yr)
  - Mux, coupler: 1000 – 10000 FIT
  - SONET equipment:  $10^5$  –  $10^6$  FIT
- The “50-ms-recovery-time” myth:
  - *Persistence of hearing*... human ear can tolerate 100-ms delay
  - For voice traffic, ok to have 50 ms recovery time
  - For data traffic, minimize recovery time as much as possible
- Need for fast recovery for data traffic:
  - Fiber cut → bundle or conduit cut... need “fiber-risk-group” awareness
  - Example: 864 fiber strands/bundle, 10 bundles/conduit, 160 lambdas/fiber, OC192/lambda
  - Total (maximum) data rate (per conduit) = 13.824 Petabits/sec
  - Up to 13,824 gigabits of data lost per ms of “down time”
  - Need fast recovery → to minimize loss of data (and revenue!)

## Protection Methods Demonstrated



1. **Single failure.**
2. **Multiple failures in same ring.**
3. **Multiple failures in two rings.**
4. **Mixed multiple failures in ring and bridge links.**