Open Undersea Cables

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Microsoft Network. Not the Internet!

• Services traverse the Microsoft WAN
• **WAN experiencing exponential ‘organic’ growth as cloud adoption accelerates**
• Trans-oceanic capacity needs a creative solution
Undersea Cables in the Azure Network

Why to own?
- Underserved regions
- Cost (if high capacity)
- Availability not sufficient

When to lease?
- Well served regions
- Cost (if low capacity)

Marea is a great example of ownership benefits.
Open cable, unique route, directly to our datacenters (i.e. got exactly what we needed)
Cable Landing Station

Backup generators (almost as big as landing station)

Shore Burial

Undersea Plow
Cable and Powering

- Shore powering with PFE and ‘virtual’ ground
  
  \[+7 \text{kV} < \underbrace{0 \text{kV}}_{14\text{kV \ total \ voltage \ across \ thousands \ of \ km}} \underbrace{-7 \text{kV}}\]

- Shunt faults and single end feeding
  
  \[+12 \text{kV} < \underbrace{0 \text{kV}}_{-2 \text{kV}} \underbrace{-2 \text{kV}}\]

- Cable fault ‘leaks’ current into sea (which grounds cable). PFE changes virtual ground and keeps cable running!
Repeaters

- 25 year lifetime at bottom of Ocean
  - Depth up-to 8000m (Japan trench)

- Repeaters every 60km – 100km (over 200 repeaters across the pacific!)

- … we get to put our name on the repeaters

- $$$

8 FP EDFA repeater
Reliability

- Cables get cut!
- It takes weeks to fix them
- Each cable is less-than 99.9% available
  - High MTTR of deep water work.
- Need 3-or-more diverse routes between regions to achieve 5-9’s

“Sharks are trying to eat the internet!” #2 most interesting fact according to mentalfloss.com
Problem Statement
SLTE

- Transponders and power management for cable
- Use latest technology to get the most out of the cable.
- Cycle SLTE every ~5 years as technology advances (cable has 25 year lifetime).
  - Cycle multiple SLTE over life of Cable.

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Capacity (today’s view 2017)</th>
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<tbody>
<tr>
<td>QPSK</td>
<td>12 Tb/s (~30Gbaud @ 37.5 GHz spacing)</td>
</tr>
<tr>
<td>8QAM</td>
<td>18 Tb/s (~30Gbaud @ 37.5 GHz spacing)</td>
</tr>
<tr>
<td>16QAM</td>
<td>24 Tb/s (~30Gbaud @ 37.5 GHz spacing)</td>
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Next Gen < 1 year away!
Options for SLTE + Cable

**Closed Systems**
- Turnkey end-to-end solution

**Upside:** Easy

**Downside:** locked into 1 vendor, limited to their equipment
Over 25 year lifetime, generally not a good idea.

**Upgradeable Systems**
- Initial build is Turnkey
- Subsequent upgrades are open to other dry plant suppliers

**Upside:** Potential for better capacity at lower cost per bit

**Downside:** Long upgrade cycles.
Lack of data on wetplant requires field trials and rolling lab

**Open Cable Systems**
- OLS like attributes
- Any third party solution for day one deployment
- Open, programmable hardware
  - Vendor agnostic API (REST)
  - Simple CLI
  - UDP based alert/alarm

**Upside:** Best upgrade costs.
Fast upgrade cycle. Flexible over 25 years.

**Downside:** Most up-front work
Upgradable System Concept

Offers SLTE / Cable disaggregation, but...

- Complex ‘surgery’ required to replace SLTE
- Cable acceptance based on SLTE performance
- SLTE and Cable Monitoring Coupled, Cable Monitoring Insufficient on its own
- Difficult to separate SLTE from Cable Infrastructure
- Rolling Lab (Field Trial) required to understand wet-plant specifications
Upgradable System – Upgrade Cycle

2 months of planning + rolling lab +
6 people, 2 weeks, 16 hour days onsite.

Needed to measure wet-plant specifications. Original turnkey system data abstracted behind dry-plant
Open Undersea Cable

- Designed specifically to be disaggregated and vendor agnostic
- Includes sufficient open hardware to monitor and maintain the cable separate from the terminal equipment
- Integrate seamlessly with Terrestrial Open Line System

Cable acceptance based on Cable Performance

No Field Trials needed for SLTE upgrades

Clear Disaggregation

SLA/Spec Tracking
Enhanced Cable Monitoring

Open Cable Interface

Cable specification measured directly in real-time

Wet-Plant
**Specification Table**

- Performance Acceptance and lifetime SLA monitoring defined on line system characteristics
  - Most notably OSNR, Power, Tilt, Gain Deviation

### 1. System Specification

1.1 Power [dBm/caller] at full loading
1.2 Slope of Tilt [dB/THz]
1.3 Gain Deviation from tilt [dB]
1.4 Equalized OSNR [dB/0.1nm] across the Passband at full loading
1.5 Span Length [km]
1.6 Span Loss [dB]
1.7 Passband Start/Stop [THz]
1.8 Average DGD across the Passband [ps]
1.9 mean PDL [dB]
1.10 Total accumulated Chromatic Dispersion [ps/nm] at 1550nm

### 2. Repeater Specification

2.1 Repeater Total Output Power [dBm]
2.2 Average Repeater Noise Figure across Passband [dB]
2.3 In-band monitoring channel(s) [THz]
2.4 In-band monitoring channel width [GHz]

### 3. Fiber Specification

3.1 Fiber Effective Area [μm²]
3.2 Fiber Chromatic Dispersion [ps/nm/km]
3.3 Fiber Attenuation [dB/km]
3.4 Fiber Dispersion Slope [ps/nm²/km]
End-to-End Design, “Packet switched CLS”

- “POP-to-POP” lowers SLTE cost, but is bad for availability and spectral efficiency.
- Landing stations are excellent locations for packet switching.
Alignment with Terrestrial Open Line Systems

The Open Cable aligns with our Terrestrial Strategy

- OSNR based acceptance
- Direct nodal control
- Disaggregated Line and Sources

“Sources”
Shorter lifetime / Dynamic tech
“Moore’s law” equipment

“Line System” or “Cable System”
Long life-time / Static tech
Photonics – akin to Highways
Port Allocation in Cloud Network

- SDN Tooling built and optimized for majority use-cases
- Subsea ports are extremely important, but operations, control, and management need to align with majority use cases.
  - No NMS, REST APIs, OpenConfig, etc..
Marea Cable

Our first completely open cable acceptance.

- Previous cables were designed closed and converted to open.

Cable acceptance separate from SLTE acceptance

- Cable will be accepted on OSNR, tilt, core size, CD, etc.
- Enhanced line monitoring separate from SLTE

“Enhanced LMS” monitoring and alarming on Power, Tilt, & OSNR
Packet Switch Capable CLS & Backhaul

Diverse from typical TA cables
>6000km Virginia (Datacenters) to Spain
19.5 dBm TOP
Extended C-band (4.5 THz)
150um^2 fiber
16-QAM capable (~20 dB OSNR @ >100 channels)
Thank you!