Exploiting Optical-Layer Flexibility for Demand-Responsive Networking

Departure talk and research overview

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Networks Lab Group Meeting

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Overview: using what flexibility to respond to what demand

Throughput

Fixed-grid WDM

Virtual topo design

Stateful grooming

OECC'15
JOCN'16

Throughput

Flexi-grid EON

Modulation and reach

Lightpath splitting

Globecom'16
ToN submission

Optical flexibility

OFC'18
Journal preparation

TDM + SDM

Resource allocation

Time-sliced SDM

Throughput & latency

OECC'17, ONDM'17
Journal preparation

Temporal TDM

Resource allocation

Optical time slice switching

Latency

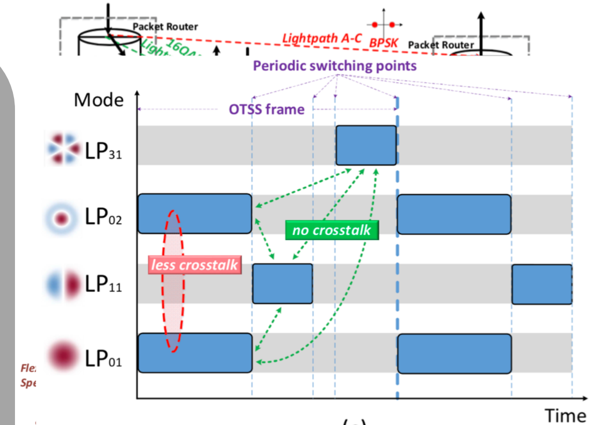
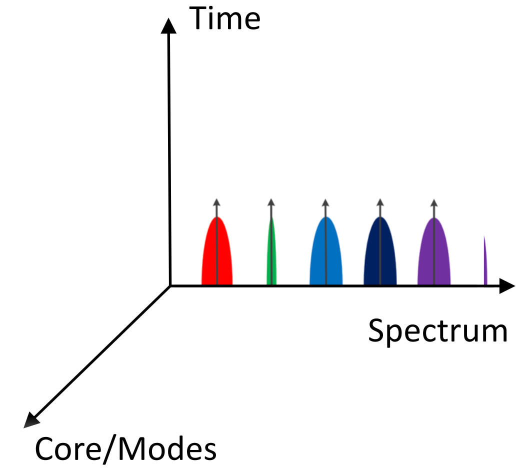


Fig. 4. Conceptual relationships among different kinds of lightpaths.



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Ongoing tutorial paper on OTSS

1. **Introduction**
   - Need for a transparent fine-grained optical network
   - Evolution of optical switching technologies
2. **OTSS Architecture**
   - Data plane
   - Control plane
   - Enabling technologies
3. **OTSS resource allocation schemes**
   - Routing, time slice and spectrum assignment (RTSA) problem
4. **OTSS use cases**
   - Data center
   - Smart grid

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1. introduction

- **Need for a transparent fine-grained optical network**
  - Energy
  - Latency & jitter
  - flexibility

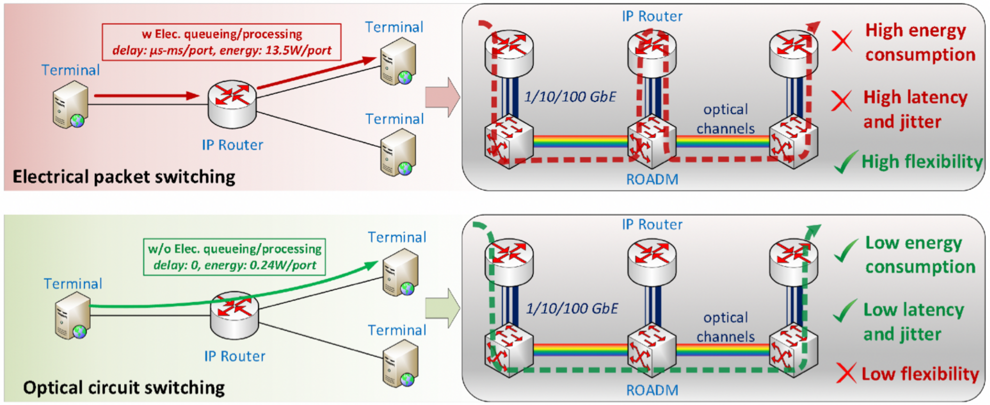
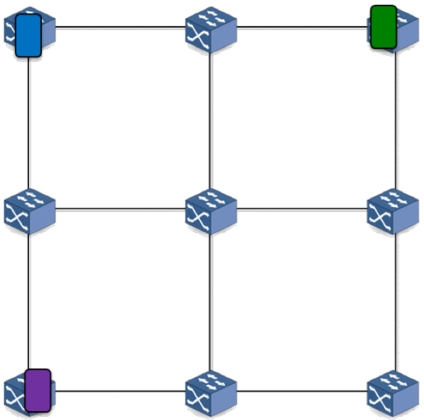


Figure 1. *Illustrative comparison between electrical packet switching and optical circuit switching.*

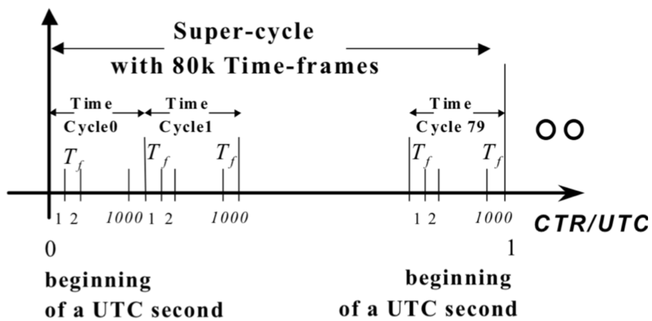
- **Evolution of optical switching technologies**
- Spectral switching: WDM or flexi-grid
- Temporal switching: OBS, OPS, Fractional Lambda Switching [1]

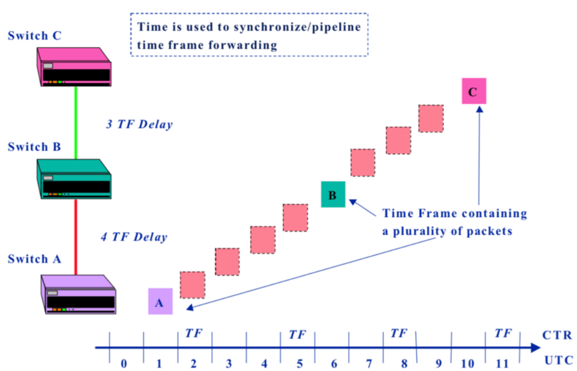


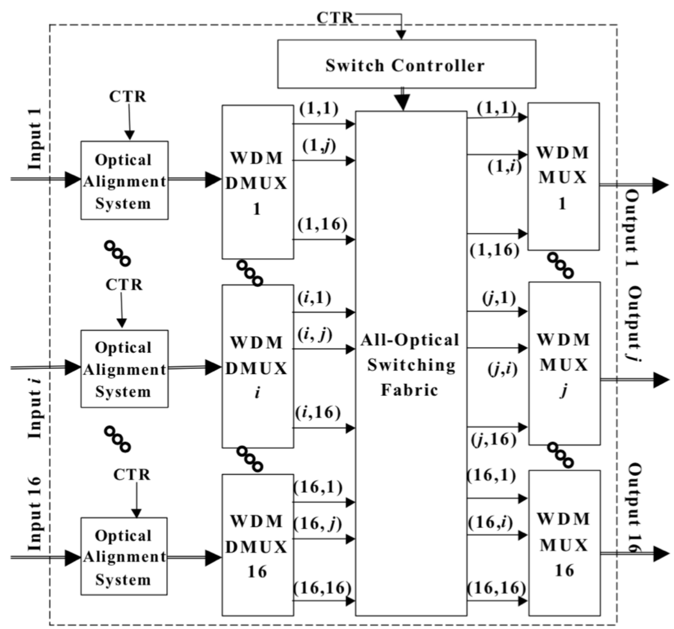
[1] M. Baldi, and Y. Ofek. "Fractional Lambda Switching." In ICC 2002.

1. introduction

- **Fractional lambda switching (aka. time driven switching) [1]**
  - Universal coordinated time
  - Pipeline forwarding







- In FλS , alignment is needed since the propagation delay on links between switches is not a integer multiple of time frames.
- Packet switching is in asynchronous transfer mode.

[1] M. Baldi, and Y. Ofek. "Fractional Lambda Switching." In ICC 2002.

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1. introduction

TABLE 1: MPLS, λ SWITCHING AND FRACTIONAL λ SWITCHING COMPARISON.

E.g., 16 input/output fibers, each with 16 OC-192 channels	**Packet switching (IP/MPLS) e.g., 1000 bit packets**	**Fractional λ switching - FλS**	**Whole λ switching**
Header processing	10 MHz	0	0
Total data units switched	$2.5\ 10^9$	$2.0\ 10^7$	0
Switching Control Speed	O(10 MHz)	80 KHz	Static
Allocation granularity	Arbitrary	Arbitrary	Whole Channel (e.g., OC-192)
Service performance	Probabilistic	Deterministic	Deterministic
Number of switching elements	At least 64K	4K (Banyan)	64K (Crossbar)

- In FλS , banyan (crossover) switch is adopted. However, in OCS, crossbar switch is adopted
- FλS requires alignment, not really Asynchronous Transfer Mode (ATM), which is still complex.
- In OTSS, we even cancel alignment, as the arrival of time slices can be any time after any propagation. OTSS is really a Asynchronous Transfer Mode (ATM) technology.

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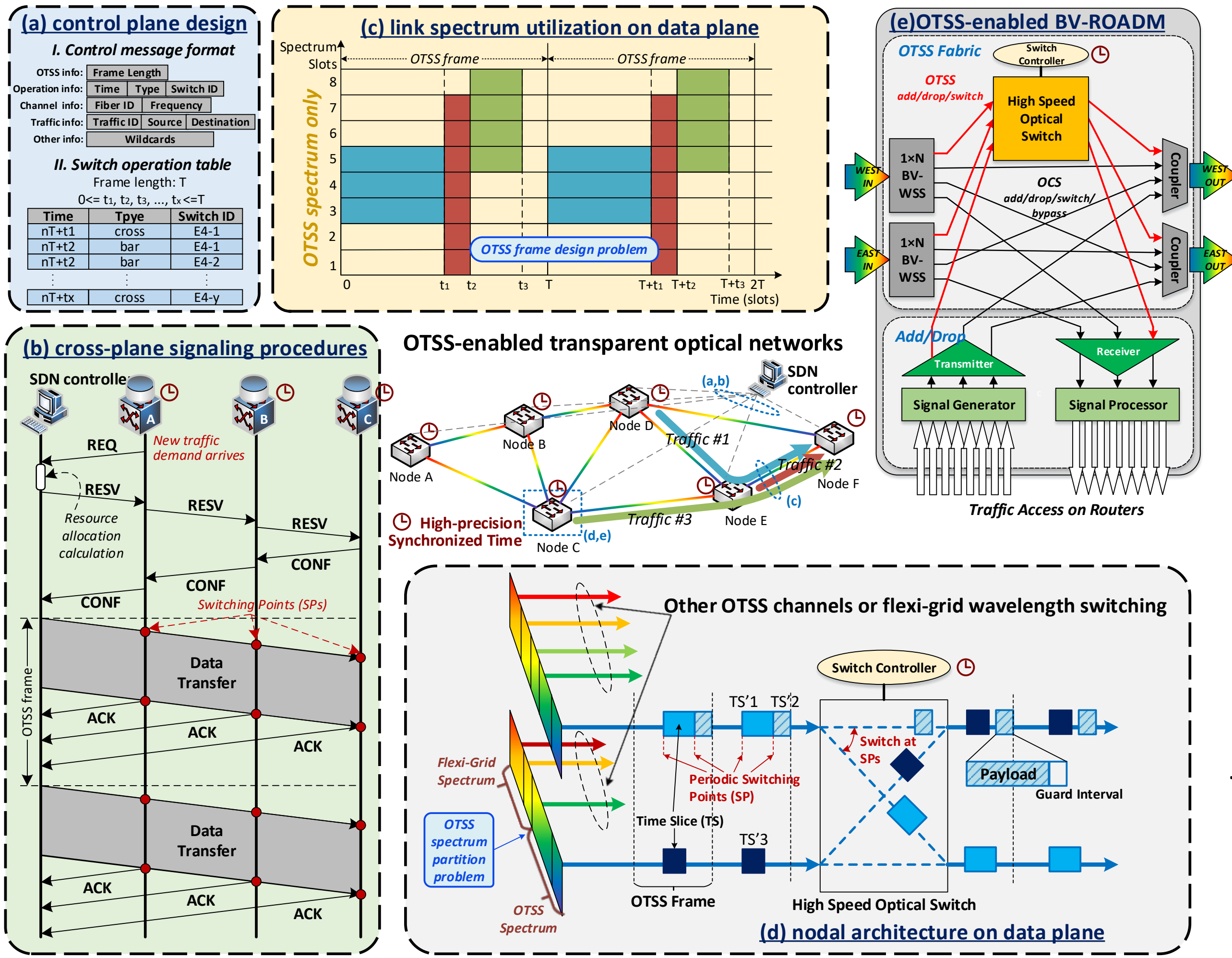
2. OTSS architecture overview



(a) Control plane
(b) Signaling
(c) Resource allocation
(d) Spectrum partition
(e) Node architecture

- Spectrum continuity constraint
- Time-slice propagation constraint
- Spectrum contiguity constraint
- Time-slice contiguity constraint

Therefore, for a traffic request, its used resource must be a **rectangular**.

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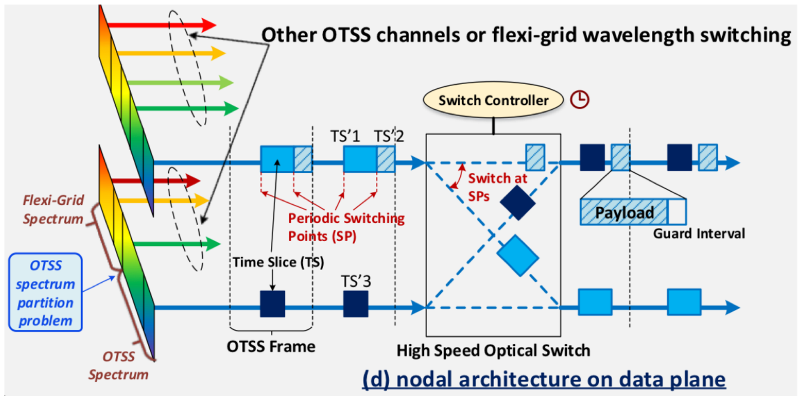
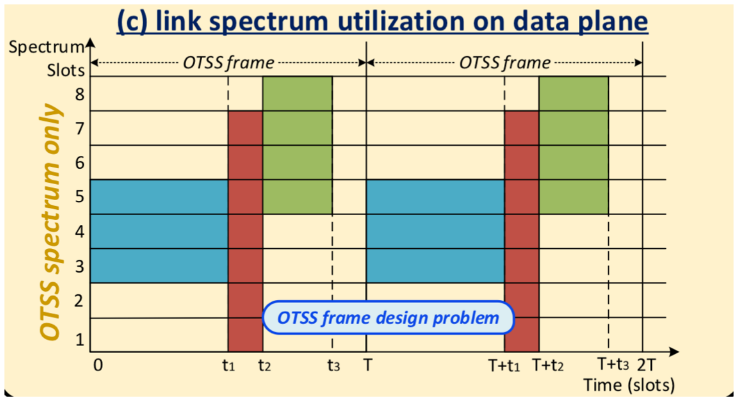
3. Resource allocation

- Dynamic Routing, time slice and spectrum assignment (RTSA) problem





- Given a traffic profile, evaluate network throughput/latency/resource utilization vs size of spectrum allocated to OTSS.

- Two policies:
  - Use larger spectrum first
  - Use larger time slice first
- Given a traffic profile, evaluate network throughput/latency vs policies.

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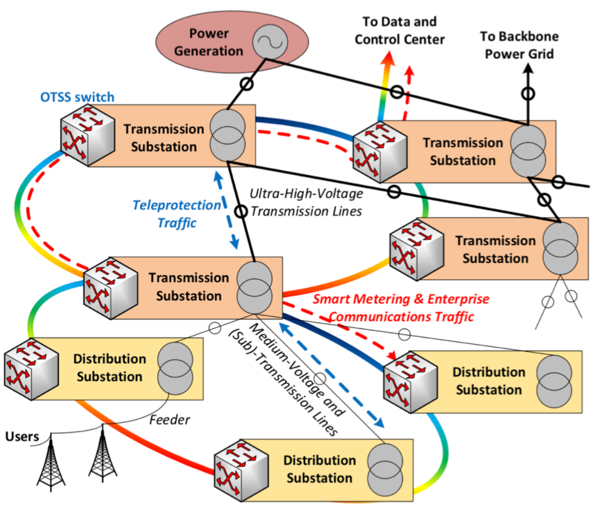
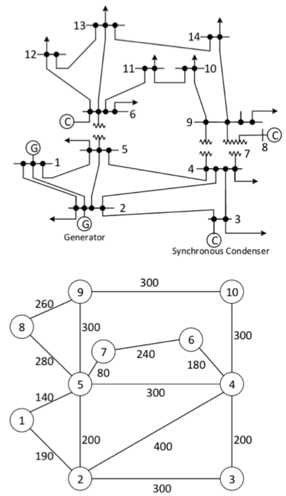
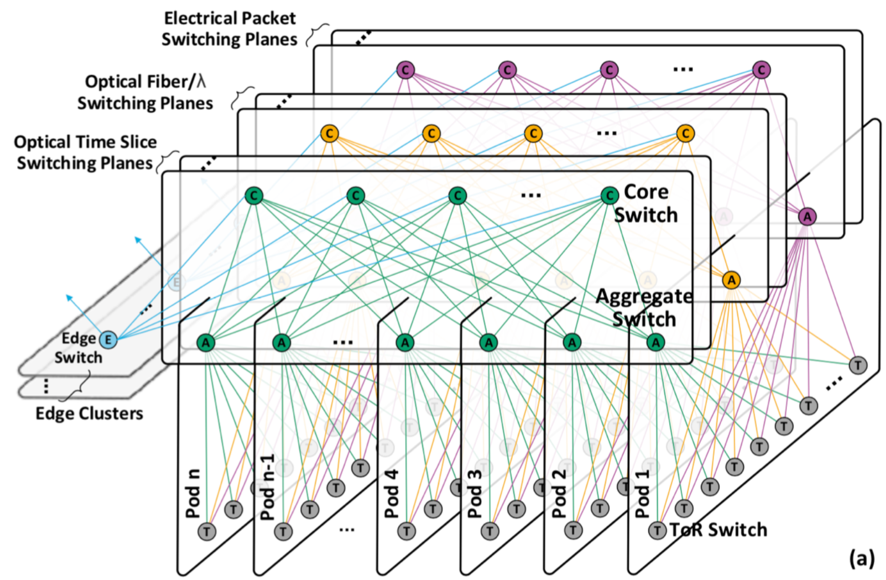
4. OTSS use cases

- Smart grid





- Data center

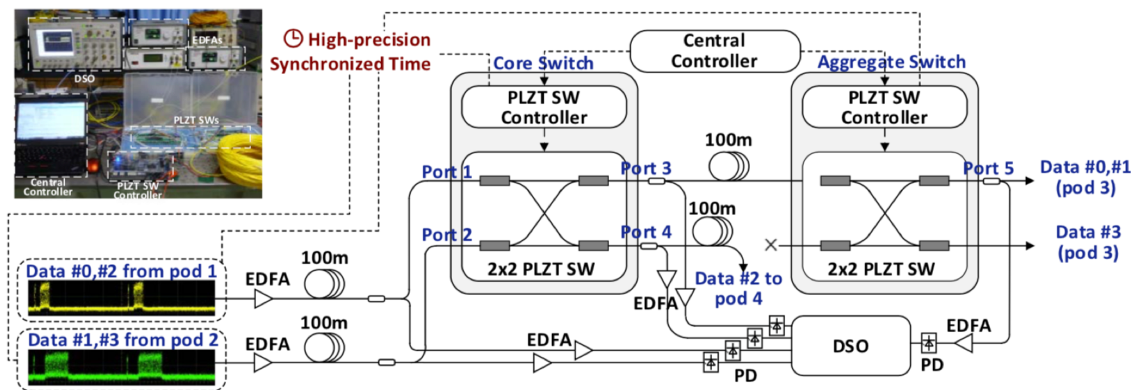


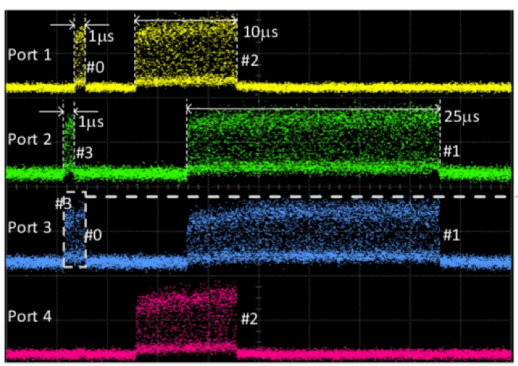
- Case evaluation: Latency performance under latency upper bound.

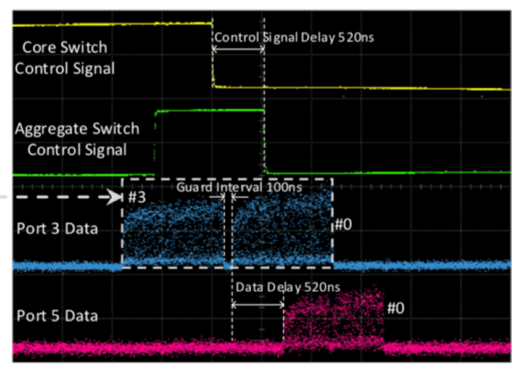
- Case evaluation: (Transparent) throughput increase for fat-tree/torus data center topology.

5. OTSS implementation

- Conduct a simple experimental implementation, to demonstrate time slice switching, and signal quality (eye diagram) after fast optical switch. Evaluate practical parameters like insertion loss, jitter performance of optical switch, etc.







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Ideas to be worked on this summer

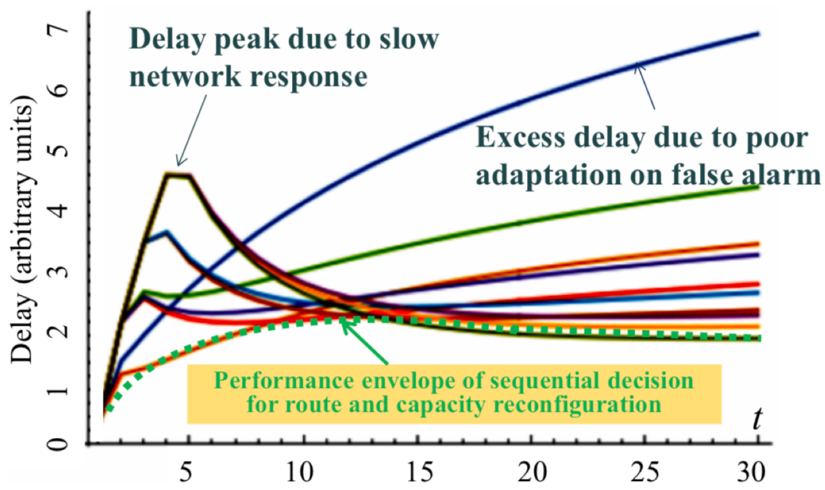

Figure 6. Delay performance of adaptation algorithm.

- When there is a sudden change in networks, how will different reconfiguration algorithm performs under different response time.

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[2] V. Chan. "Cognitive Optical Networks." In ICC 2018.

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Thank you for attention!

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