

Multi-Degree ROADM's with Agile Add-Drop Access

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Abstract: The rapid planning and deployment of reconfigurable all-optical carrier networks requires next-generation ROADM's that can support unlimited add-drop access with very high flexibility. We review a cost-effective multi-degree ROADM that can support up to 100% add-drop traffic capacity with unparalleled agility and minimal pre-planning. The ability of this ROADM to share, distribute and therefore minimize the need for local resources such as regeneration, wavelength-conversion, broadcast, and multicast cards, to the lowest possible required, is discussed for overall network level savings.

Keywords: optical switches, photonic cross-connect, wavelength division multiplexing

Introduction

With the rapid deployment of broadband access and high-bandwidth applications such as grid computing, next-generation core networks are expected to exceed hundreds of terabits per second [1, 2]. While the DWDM capacity increase will migrate to spectrally efficient data rates of 40 Gbit/s and beyond, photonic network agility will be enabled by highly flexible and functional multi-degree ROADM's (MD-ROADM). Degree-2 ROADM's are already being deployed in carrier networks to provide all-optical pass-through of express traffic at add-drop sites, which eliminates expensive and redundant OEO transponders (transmitter and receiver interface cards). As the core network is evolving into inter-connected rings and mesh architectures, MD-ROADM's with support for beyond four degrees (number of DWDM network ports terminating at the ROADM) becomes a necessity. Concurrently, provisioning for unlimited add-drop traffic capacity with minimal pre-planning is an important MD-ROADM design requirement. As add-drop transponders dominate the network cost, MD-ROADM's also need to provide highly flexible network access for each add-drop port so that dynamic reconfiguration, such as wavelength re-routing (e.g. load balancing) and network restoration, does not require additional pre-deployed transponders [1, 3]. Similarly, the ability of MD-ROADM's to share other local access ports, such as regenerators and wavelength converters, among all DWDM network ports and for any wavelength reduces the number of these resources to the absolute required minimum.

2. MD-ROADM Add-Drop Agility Criteria

The following MD-ROADM add-drop flexibility criteria enable efficient use of each tunable access resource (transponders, regenerators, etc) for on-demand and high-bandwidth network configuration and restoration:

- **Direction-less Access:** Any transponder (TXR) has non-blocking access to all DWDM network ports (Fig. 1(a)).
- **Colorless Access:** Any (tunable) transponder has wavelength transparent access to all DWDM network ports (Fig. 1(b)).
- **Contention-less Access:** Any two or more transponders can simultaneously occupy the same wavelength into different DWDM network ports (Fig. 1(c)).

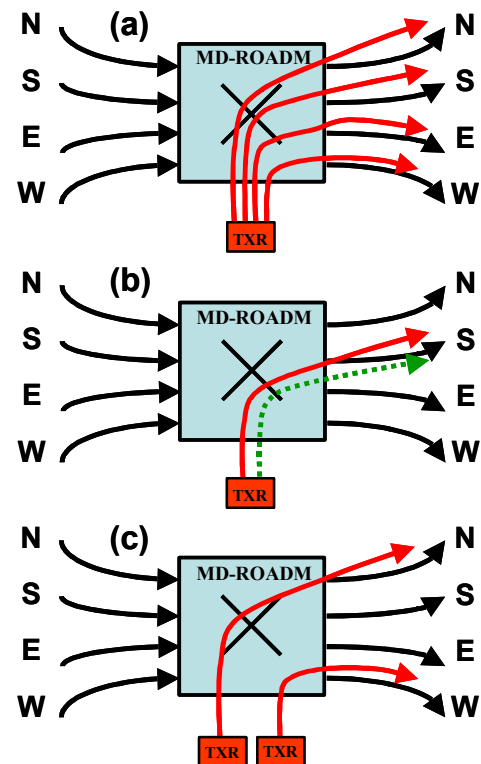


Figure 1 : MD-ROADM add-drop flexibility criteria a) direction-less, b) colorless, and c) contention-less access

In addition to the above flexibility criteria, which simplify the network architecture and optimize the use of access resources, MD-ROADM's also need to meet the following operational add-drop access criteria:

- **Modular Add-Drop:** As it is hard to forecast required future add-drop access capacity, the MD-ROADM should allow simple modular add-on capability of transponders.
- **Low Initial Cost:** As initial deployment may require only a few transponders, the cost of any pre-deployed add-drop optics (for future installation) needs to be low (for example, if an EDFA or WSS are used at the add-drop

path, the initial cost per add-drop wavelength will be very high if only a few transponders are initially active).

- **Minimal Pre-Planning:** As the ROADM site can grow to support several more DWDM network ports in the future, each add-drop port needs to be able to adapt to the network growth with minimal pre-planning.
- **Add-Drop Fiber Management:** Minimal fiber cabling from the ROADM to the transponders is needed from an operational perspective. Ideally, each transponder should only require a single bi-directional cable.

3. MD-ROADM Architectures

Fig. 2(a) shows the MD-ROADM based on a typical broadcast-and-select architecture using 1:K WSS's, where K is the number of port (other variations of this architecture can be found in references [2] and [4]). Since each WSS device uses N-1 ports as DWDM network ports (N), the remaining K-N+1 WSS ports can be used for colorless add-drop access. However, since K is typically less than 10, the number of transponders that can be supported is very limited. In 40-wavelength DWDM systems, the required number of WSS ports (K) is well beyond 20 even for low node add-drop ratios and requires very challenging port counts for high number transponder support as shown in Fig. 3(a). Furthermore, each transponder needs to be connected to all N WSS devices for directionless access, which inefficiently consumes N WSS ports with a single transponder. For example in a degree-8 ROADM, each transponder would require a 1x8-access switch (or splitter) as shown in Fig. 2(a).

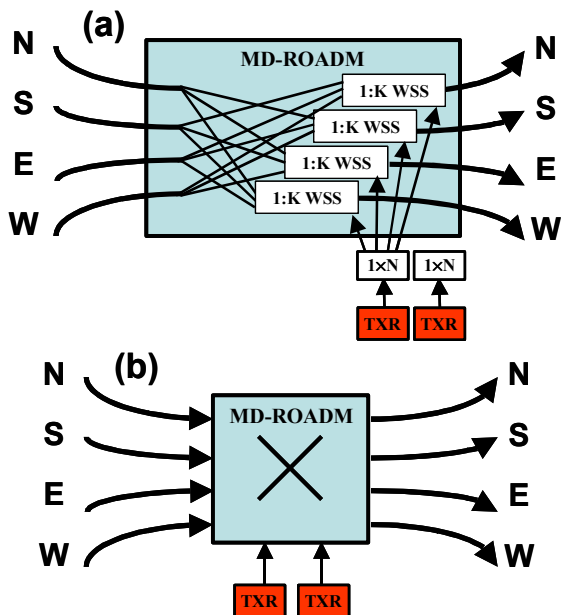


Figure 2 : MD-ROADM based on a) 1:K WSS and b) 3-D MEMS cross-connect (only the add path is shown for simplicity)

The MD-ROADM with the highest add-drop agility is shown in Fig. 2(b) [4, 5]. The 3-D MEMS based ROADM core is not only a true N:N WSS, but it also provides up to 100% add-drop capacity, each with colorless, direction-less and contention-less access. This architecture also provides

operational savings as minimal pre-planning is required for future growth. The fiber management comparison shows that regardless of nodal degree, the 3-D MEMS MD-ROADM requires only a single bi-directional fiber cable per transponder for access while the WSS is dependent on various node parameters and does not scale (Fig. 3(b)).

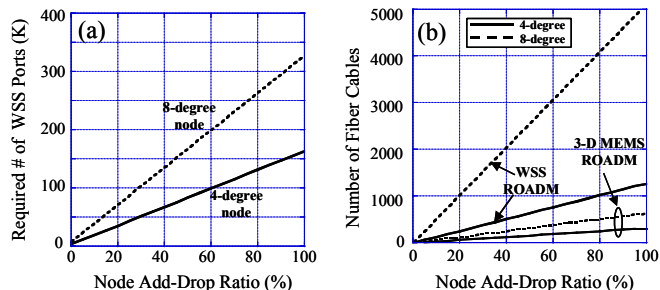


Figure 3: a) Required number of WSS ports (K) for agile add-drop access, b) Comparison of MD-ROADM fiber management (both figures assume 40-wavelength DWDM systems)

Due to the inefficiencies of local add-drop access in WSS based MD-ROADM's, other WSS access architectures optically aggregate transponders, such as using additional WSS's and EDFA's (instead of a 1xN-access switch in Fig. 2a) before switching into the MD-ROADM [2, 4]. However, these access architectures impose other limitations, such as wavelength contention among transponders, and an increased cost per add-drop wavelength, which will be discussed in detail.

5. Conclusion

This paper presented agile add-drop requirements for MD-ROADM's. The ability to provide up to 100% add-drop ports, each with the highest flexibility while preserving operational ease is best achieved using 3-D MEMS ROADM's.

6. References

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7. Glossary

- ROADM: Reconfigurable optical add drop multiplexer
- DWDM: Dense wavelength division multiplexing
- WSS: Wavelength selective switch
- 3-D MEMS: Three-dimensional micro-electro-mechanical systems