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Analysis of Innovations in OTN Interconnects

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Abstract: Service providers (SP) are constantly attempting to match their network to cater to rapidly evolving offerings from content providers and digital application providers. Layered and siloed architecture in tradition Service Provider Network, requires higher management and operational costs and pose challenges in rapidly scaling. In order to solve these problems, alternative approaches are being tried out. Naturally, the approach from equipment manufacturer (OEM) could be different from that of Operator consortium or open-source community. Hence it’s prudent to visualize these three alternative architectures side-by-side and analyse them simultaneously. This paper focuses on analysing these three alternative architecture approaches with respect to each other. This analysis brings out the common features as well as key differences in these three approaches. Additionally, the analysis presented in this paper enables a practical insight into offered choices, provides a new tool to check fitment of the solution and provides a ready list of key design considerations. At present, no other article covers these useful guiding points and is a unique contribution.

Keywords: Routed Optical Network (RON), Open Disaggregated Transport Network (ODTN), Virtual Online Termination Hardware Abstraction (VOLTHA), Open Network Foundation (ONF), Software Defined Network (SDN)

I. INTRODUCTION

Service Providers are finding ways to create a more flexible infrastructure that meets the increasing data demands arising from IoT, 5G and cloud-based applications. Internet traffic has seen a compounded annual growth rate of 30 percent or higher over the last five years because more devices are connected, and more content is being consumed [1]

On one side such infrastructure is expected to meet demands on the scale required for high-value services. On other side the network is also expected to maintain existing revenue offerings by making them more cost efficient. These challenges exist, primarily because:

a) most networks are layered and siloed into separate technologies

b) Adding a service can add cost at each layer. Multiple line cards get involved for traffic hand-off between networking layers.

c) Layered architecture requires manual service stitching across network domains, posing challenges to end-to-end cross-loop automation required for automated operations (remediation) and shorter service lead times [2]

a) Redundant protection at those layers also results in poor network utilization and additional complexity

b) Lack of programmability of one layer (e.g. optical) affects the overall benefits gained by flexibility that another layer (e.g. IP) can support

It can be stated that Operational costs (OpEx) are nearly 75-80% of overall Network costs. The high-cost pain points are in the complexity of managing multiple layers, the power and space demands of each of the layer, and lifecycle management [3]. Traditional solutions build IP networks on top of an optical layer to increase capacity and reduce the number of expensive router ports. That was and is considered the router bypass option that included reconfigurable add/drop multiplexers (ROADMs). These router bypass networks leveraged the DWDM layer to liberate routers of the massive transit traffic on the network to reduce the cost of big, expensive routers. Accordingly, services today run over routers, Optical Transport Network (OTN) switches, optical transponders, and Reconfigurable Optical Add-Drop Multiplexers (ROADMs) [3]. A traditionally layered architecture is usually managed by different departments. Organizational boundaries slowed the potential to leverage advances in automation. With present architecture of multi-layered components, it is difficult to properly optimize any network.

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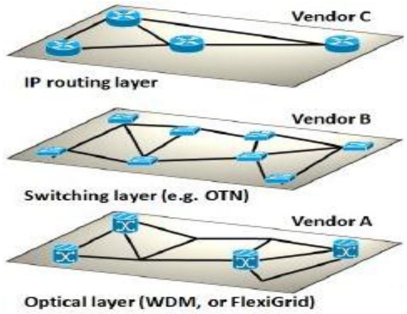

Fig1: Traditional networks with multiple layers

In order to solve these problems, alternative architecture and approaches are put forth by equipment manufacturer (OEM), Operator consortium and also open-source community.

1) Cisco Routed Optical Network (RON): As a starting point, reducing number of 'moving parts' is essential. In past, IP and optical integration (IPoWDM) has suffered from density tradeoffs [3] and different technological advancement cycles. But recent development of RON (© Cisco), shows promising solution and strong option.

2) Another approach originates from organizations building custom networks for their specific requirements. Present transport equipment is vertically integrated, having control cards for various functions (line cards, amplifiers, mux, transponder) into single monolithic NE (chassis). The Open Networking model is driven with a focus to make variety of equipment work together to satisfy individual needs of performance and scale. This underlines a need to establish a standard API and data model in order to realize an Open disaggregated transport network (ODTN).

3) Yet another approach works on principal of abstracting the underlying complexities from the north-bound system. This allows the northbound system to alienate the layered network view and instead appear flat. Virtual Online Termination Hardware Abstraction (VOLTHA) achieves this abstraction. On its northbound interface, VOLTHA abstracts the PON network to appear as a programmable Ethernet switch.

A detailed insight into each of these three alternatives is presented in three subsequent sections.

II. CISCO'S ROUTED OPTICAL NETWORK (© CISCO)

With the vision for 'Future Network', Cisco has come up with an innovative architecture by bringing true convergence of the IP and optical domains. This new network architecture overlays the current optical switching layer[4]. It puts the switching functions into the router layer by directly integrating high capacity optical interfaces (e.g. 400G) on the routing devices. The architecture relies on a single control plane that is based on IP/MPLS for a converged IP and optical network. RON architecture is able to achieve this without having to compromise on deloading the IP fabric [2], which was an issue in earlier IPoWDM (density tradeoffs) based solutions. This simplifies the management of the entire network and is more effective. This architecture simplifies operations (OpEx benefit) and improves capital efficiency (CapEx benefit) [5].

Routed Optical Network deploys IP routing architecture that is characterized by a single networking/switching layer in the IP domain and simple point-to-point optical infrastructure without the high cost and complexity (unlike ROADM). This new approach is made possible by recent evolution of silicon technology used in two main areas[6]:

- Network Processing Units (NPU) used in Layer 3 routers, and
- DSPs used in coherent transmission optical interfaces.

The RON architecture is defined by two primary initiatives:

- Integration of 400G transponders function[2]: New 400 Gbps routers are delivering massive increases in router scale and capacity, resulting in a significantly lower cost per bit router. DCO optics have decreased in size and power consumption. Hence it is feasible for 400G DCO optics to reside on a router card at much higher densities.
- Service convergence: Modernizations led by Cisco allows legacy TDM traffic to be carried over the packet network. Moreover it enables new OTN services also carried over packet networks with matching SLAs. This service convergence is made possible due to integration of OTN aggregation and switching functions. Innovations in optics are leveraged to realize Universal line cards. In such Universal line cards, it is possible to mix grey and colored (400GbE ZR/ZR+) optical interfaces.

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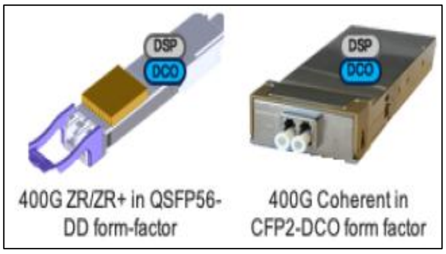

Fig2: 400G Pluggable optics with DCO integrated

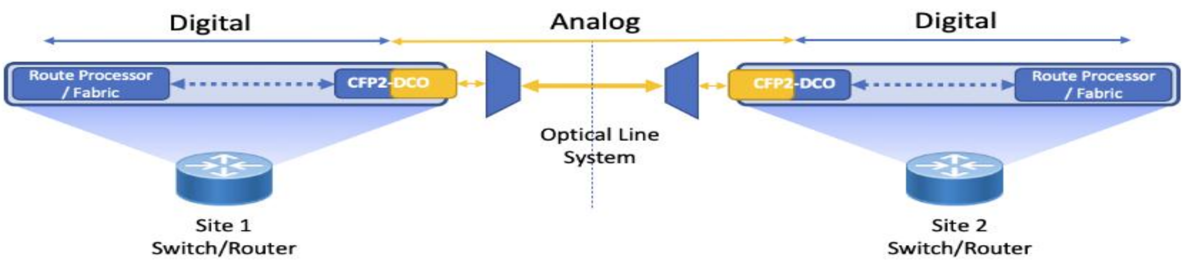

Fig3: DCO DWDM transport within the router or switch (source WWT.2020)

The Routed Optical Networking (RON) architecture takes advantage of the technology advancements. RON effectively enables true network capacity optimizations. Moreover it provides network simplification accomplished by the collapsing of layers. Thus RON solution brings together the standardized 400G ZR/ZR+ optics and massive routing scale with pluggable. This removes the transponders and replaces with 400G ZR standardized coherent optics. This way IP and the optical layers, which had operated separately in earlier networks, can be unified [7]. This makes the network leaner and improves network economics.

III. OPEN DISAGGREGATED TRANSPORT NETWORK (ODTN)

As can be seen in schematic representation in fig.1, Optical components are present in multiple layers. Optical systems are usually made up of a number of optical elements. These elements are held together with one or more mechanical elements (e.g. 19' Chassis).
A common practice in Data Centers(DC) is to use standard transceiver ports in an Ethernet Switch, for connecting 100G traffic within DC. For long-distance and large amounts of data between sites, multiplexer combines various traffic outputs (from switches/routers). A transponder then carries this aggregated signal onto DWDM transport network.[9] A complete transponder solution offers additional functions (such as amplifier, signal conditioning etc). This results in vertically integrated system. In addition to the specification, the details of such optical system are influenced by the manufacturing capabilities of the supplier.

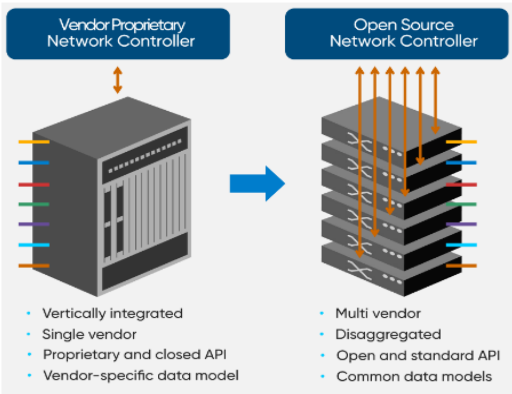

Fig4: Vertically Integrated to Disaggregated Optical NE

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Technical complexity posed by analog nature of long distance DWDM optical communications has driven the need for the current vertically integrated solutions in the market. ODTN's approach is designed to change this by assuming that every optical link will use a matched pair of transponders from a single vendor. The network can use a different brand of transponder for each link. These transponders can run over an open line system from yet another vendor [10].
Open and Disaggregated Transport Network (ODTN™) is an initiative led by operators. This project aims to build data center interconnects (DCI) using following key aspects [11]:
- open and common standards (OpenConfig for Transponders, TAPI for OLS)
- disaggregated optical equipment (Edge-core CASSINI)
- open source software (ONOS, Yang based network models)

ODTN plans to enable a white-box optical 'peripherals' ecosystem [10]. This allows multiple components (not necessary from same vendor) to be combined and built into complete solutions. Hence Vendors can focus on building a specific component (e.g. transponder) without having to build a complete solution leading to accelerated innovation and lower costs. Operators can have the freedom to select best-in-class components and avoid vendor lock-in. Disaggregation also enables a better life-cycle cost approach since optical components can be interchanged post lifespan, without modifying network architecture.

As per ONF, ODTN is the only optical transport open source project [12]. It is first project to build open source software stack for control and management of optical networks. Innovation in ODTN project focuses on disaggregating the components of the network. It strives to become optical network of choice by providing open software to control multi-vendor components.

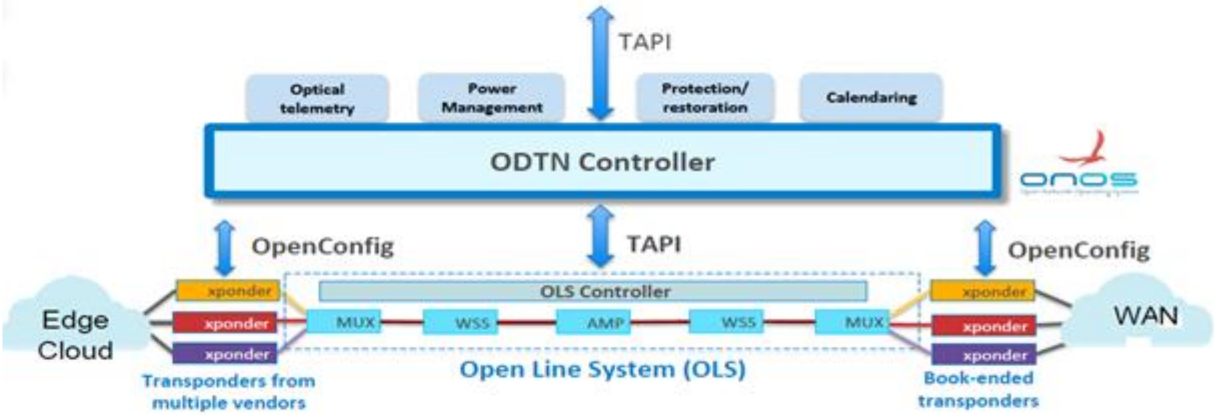

Fig5: New Network Architecture with ODTN implementation (Ph1) Courtesy ONF

In first phase of implementation, ODTN project has successfully demonstrated disaggregation of transponders from OLS (optical line system). In this architecture, ONOS acts as a central controller and connects to OLS controller at south-bound via OpenConfig. ONOS uses standard TAPI interface for north-bound apps integration. Various network equipment vendors have participated to produce a standardized and disaggregated transponder e.g. Infinera XT3300, Edge-core CASSINI. In this deployment, the optical domain controller sees the open line system (OLS) as a "big switch" [13] with I/O ports (connected to transponders), thereby reducing layers.

The subsequent phases (Ph1.5, Ph2.0 and so on) has plans to further enhance this architecture. More innovations are happening in further disaggregation of complex components (e.g. innovations from Edge-core, Adva [14]). On the standardization side, its being considered to include ONOS enhancements with features such as Multi-device transaction, config state management.

IV. VIRTUAL ONLINE TERMINATION HARDWARE ABSTRACTION (VOLTHA)

VOLTHA™ is an open source project to create a hardware abstraction for broadband access equipment. It supports the principle of multi-vendor, disaggregated, "any broadband access as a service" for the Central Office [15]. VOLTHA currently provides a common, vendor agnostic, GPON control and management system, for a set of white-box and vendor-specific PON hardware devices. With the upcoming introduction of access Technology Profiles, VOLTHA will support other access technologies like EPON, NG-PON2 and G.Fast as well.

On its northbound interface, VOLTHA abstracts the PON network to appear as a programmable Ethernet switch to controller [16][17]. This helps in reducing the layered view as well as complexity in managing various layers separately.

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On its southbound side, VOLTHA communicates with PON hardware devices using vendor-specific protocols through OLT and ONU adapters (OpenONU adapter written in Go).

Access as a Switch: Makes an access network look like an abstract programmable switch

Evolution to virtualization: Works with legacy as well as virtualized devices. It can run on the device, Or on general purpose servers, or in a virtualized cloud.

VOLTHA-INFRA: ONOS, ETCD, KAFKA [16]

VOLTHA-STACK: OF-Agent, Core, OLT and ONU adapters [16]

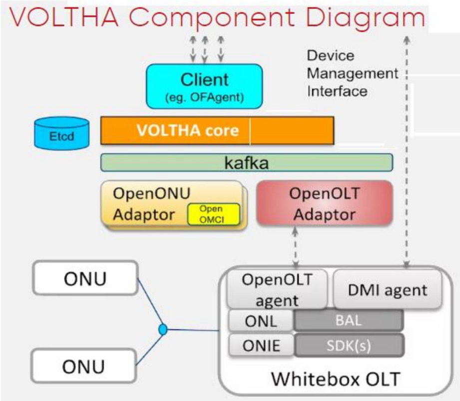

Fig6: VOLTHA Component Diagram (Courtesy ONF)

VOLTHA is used in compositions from elastic multi-rack systems to micro-plugs. VOLTHA provides control and management abstraction of low-level silicon, that is typically used for composing Access Node functions in a cloud deployment. Thus VOLTHA abstracts silicon to make it easier to use different hardware in a vendor-neutral and technology-neutral way. It disaggregates the hardware from software and provides features and functions in a cloud-centric way. Its core purpose is to abstract the access device silicon, and make the access network look like a simple programmable Ethernet switch [18].

V. ANALYSIS

Traditional multi-layer network architecture poses limitations for new-age requirements. The three solutions described in above section shows a way to overcome these limitations and fulfil the requirements. The following section presents the analysis of these solution approaches:

a) It's interesting to observe how the similarities of all these three solutions and key differences between them.
b) The author has given guidance and his view point to help the network architects, about when to choose which of these solutions or which solution is suited for what type of requirement.
c) Once the choice of which of the three approaches to go for is made, the designers need to list down key design and deployment considerations. The author has highlighted some key considerations to help in this stage. These can be used directly or by tailoring to specific need.

These guiding points are useful to architects and designers. It is a unique contribution covered by this paper.

A. Similarities between the three approaches

1) All 3 attempts to simplify network deployment and reduce complexity in NW cabling and cross-connects, thereby reducing management overhead
2) All 3 approaches try to abstract Optical interfaces into a programmable model. This is a marvelous achievement for all the three approaches. All the three approaches make nil (or minimal) change to Ethernet ports and IP transmission.
3) All 3 approaches work with SDN controller in their North bound. In other words, these solutions lie southbound to SDN controller and are part of Data Plane of SDN.
4) All 3 approaches have dev-ops deployed in their development cycle, to ensure continuous innovation and upgrade. This assures the innovation and further enhancement.
5) All 3 technologies can be used in CORD to help in Data center modernization.

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B. Differences between the three approaches

1) Cisco RON has key focus on reducing multiple data-planes into one. ODTN has focus in disaggregation of verticalized optical equipment. Voltha focuses on abstraction of OLT into an virtual Ethernet switch.

2) The entity behind these three innovations is different.

a. Cisco-RON is Cisco's innovation and part of their "internet of future" program.

b. ODTN project is conceptualized and promoted by consortium of Operators under ONF.

c. Voltha also falls under ONF, but is it a part of open-source initiative.

3) Voltha combines various open-source solutions. ODTN has few open-source components in it, along-with facilitating innovation of disaggregated components which adheres to common open specification. To some, Cisco-RON solution may appear as 'not-open' or OEM specific solution. But it should be noted that points like allowing Pluggable photonics, using standard QSFP form factor, working with segment routing gives it a flavor of open pluggable platform.

4) Cisco-RON would usually operate at 400G range. ODTN can deploy even higher ranges (e.g. CDC). Voltha is mostly on 100G (or 200G) range. This also can be practically observed from current deployments. Voltha is mostly deployed as a Broadband Access side solution (mostly as a part of SEBA). ONF suggests ODTN to be deployed in Core. Cisco RON would fit in Metro-core and core too.

5) Cisco literature [8] indicates that Cisco-RON works better in conjunction with Segment routing. Whereas ODTN and VOLTHA can work with normal path selection.

6) VOLTHA is comparatively older solution and can be seen practically deployed in various client networks. Cisco-RON and ODTN are newer compared to VOLTHA.

C. Selecting the right architectural solution fit for the purpose

Guidelines to decide which of the three solutions is suitable for which scenario, are given in the form of questionnaire. This can be used by Architects as a tool to arrive at the fitment. This tool helps in getting clarity in situations where all the three solutions appear suitable and the architect needs to justify which one is right fit. This questionnaire tool can also be used during Requirement Analysis phase or even during Business case preparations.

a) If the answers to all or most of the below questions is "Yes", Cisco-RON is a better suited solution.

TABLE I SELECTION QUESTIONNAIRE 1

No	Question	Ans
1	Are most of the existing and new services to be catered by the network are IP and data centric? Is there a decision to spend (CapEx) on IP data nw	
2	Are the legacy (TDM, Wavelength) services transient and at relatively low volumes, such that influence they exert on the next gen network architecture is minimal? Are investments in this part of network coming to End-of-life in 15-18 months?	
3	Is it acceptable to re-architect the network specifically for IP traffic without compromising services offered (e.g. reduction of optical ports/OLT cards)	
4	Is the present network having higher %age of Cisco NEs? OR Is there strategic decision to increase the footprint of Cisco NEs and devices?	
5	Does the existing network already have (or will have) other components of Cisco Converged Transport platform e.g. Cisco SDN controller.	
6	Is the network under question, connecting large Data Centers, having Cisco IP network present at both sides	

b) If the answers to all or most of the below questions is "Yes", ODTN is a better suited solution.

TABLE II Selection questionnaire 2

No	Question	Ans
1	Is it expected that solution is built using open and common standards and open source software	
2	Is the solution expected to build and manage next-gen data center interconnects (DCI) between core sites	
3	Is the network being built for new services which will require more frequent scaling/re-scaling across these core sites, for significantly high volume of data? i.e. is it expected to have flexibility at high capacity (as against the traditional approach where high capacity was fixed)	
4	Are there multiple verticalized OTN/DWDN/CDC-ROADM elements at both ends, in present (to be changed) architecture.	

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5	Is it expected that the new architecture allows optical components to be interchanged post lifespan, without modifying network architecture	
6	Is a budget/investment approved for these new-age disaggregated optical peripherals? Are the new-age optical peripherals from Adva, Edge-core, Infinera etc already evaluated to be included in new architecture.	
7	Is the new architecture going to be rolled out in phase wise manner, instead of in-one-go?	
8	Is there a high element of heterogenity which would force new architecture to have one central Controller communicating with multiple domain controllers in control plane	
9	Is there already an availability of resources and competency with ONOS, OpenConfig etc	

c) If the answers to all or most of the below questions is "Yes", Voltha is a better suited solution

TABLE III Selection questionnaire 3

No	Question	Ans
1	Is the expected that solution is built using only open and common standards, and open source software	
2	Is the solution expected to create a hardware abstraction for broadband access equipment, for a telco central office.	
3	Is SEBA already part of the solution (/proposed solution)	
4	Is the new architecture going to be applied on current PON network (PON hardware devices)	
5	Is the traffic and data handled by the each of PON devices is around 100G-200G range	
6	Is it expected that the PNF and VNF components will co-exist in the final architecture. Is the CO 'cloudification' expected to continue in-parallel to network re-architecture.	
7	Is it expected that new proposed architecture should be implemented using a stable release available and should replicate the success from other similar deployments	
8	Is there already an availability (in-house or with partners) of resources and competency with SW systems such as ONOS, Yang, NetConf etc	

It should be noted that the questionnaires would evolve and more questions could get added to strengthen the choices (e.g. Is the new architecture expected to serve MEC? Are there protocols other than IP/MPLS in current architecture).

D. Key design and deployment considerations

Once the choice is made, following important considerations need to be looked at. To enable designers with a ready list of design considerations to begin with, following points are quite useful. This will enable designer to gather early insight into these specific aspects requiring additional attention.

- **Monitoring and Network management**: How will the new devices/line-cards be monitored and managed. Will existing NMS/OSS be able to discover, monitor and manage it?
- **Automation**: Most of the operators are looking at network operations automation. How the new process of automation affects the implementation of above choices, is a key design aspect.
- **PNF and other elements integration**: The network environment at most of the operators will have a combination of traditional devices along with virtualized devices and also VNFs.
- **Interoperability with traditional layered network**: Certain parts of the network will undergo transformation by implementing one of the above solutions. But still certain parts (e.g. same operators NW in other geo or some other network coming via acquisition) will always exist in traditional form. In such situations, the design has to ensure how these will Inter-operate.
- **SDN Controller consideration**: Typically it can be assumed that standard SDN controller will work well with standard Data Plan deploying OpenFlow. But in cases of the three solutions mentioned above, it is a good practice to reconfirm if the SDN controller will be able to fully utilize the benefits presented by these innovative Data Plane elements. E.g. It's advisable to use Cisco SDN controller for Cisco RON. It's advisable to use ONOS in case of ODTN.

- **Network Modelling**: All the three approaches present the optical interconnects in non-traditional way. Hence network modelling will need special consideration at design time. (e.g. VOLTHA modelled as Ethernet-switch)
- **Security and Access Management**: New design and new devices will certainly bring new types of threats and challenges for ways of access management.
- **Performance**: While functionally, each of the three approaches provides solution to older problem, the design has to ensure that the performance remains at least equal to older architect (e.g. protection switching under 50ms)
- **Release management and image preservation**: In all of the three approaches, a common point is continuous innovation and enhancements. Hence current image of network will need to be maintained frequently (unlike in past network where only data needed to be preserved).

VI. CONCLUSION

Traditional layered Network Architecture is not suitable for the data demand, usage pattern and scaling requirements of new technologies and services. Three innovative solutions were described in this paper. These solutions originate from completely three different industry players (one from OEM, second from Operator group, third from open-source). Its interesting to see that, when analyzed side-by-side these three solution indicated some common features. Analyzing them side-by-side was able to give this unique insight into the common direction such innovations would take. The paper also lists down the major differences between these approaches. A questionnaire based tool is provided in the paper that helps architects to check suitability and select one of these three architectures. In addition, a ready list of key design considerations is provided as a guiding information for design/implementation phase.

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TABLE IV Glossary of terms

CAPEX	Capital expenditure		OPEX	Operating expenditure
CORD	Central Office Rearchitected as a Data Center		OSS	Operations Support System
DCI	data center interconnects		OTN	Optical Transport Network
DWDM	Dense Wave Division Multiplexing		PON	Passive optical network
MPLS	Multiprotocol label switching		ROADM	Reconfigurable Add/Drop multiplexers
NMS	Network Management System		RON	Routed Optical Network (© Cisco)
OEM	Original equipment manufacturer		SDN	Software Defined Networking
OLT	Optical Line Termination		SEBA	SDN enabled broadband access
OLT	Optical Line Termination		TDM	Time Division Multiplexing
ONF	Open Networking Foundation		TDM	Time Division Multiplexing
ONOS	ONF controller platform		VOLTHA	Virtual OLT hardware abstraction

REFERENCES

[1]. Cisco Annual Internet Report (2018–2023) White Paper
[2]. Cisco White Paper “Solutions for IP Optimized Optical Transport” ©2020
[3]. Cisco Executive Brief “A Transformative Architecture Challenging Present Modes of Operation” ©2020
[4]. Cisco at a glance ©2021, article “Evolution to Routed Optical Network”
[5]. IDC Info-brief Mach 2021: “Routed Optical Networking: The Road to a Converged Network”
[6]. ACG Research Report ©2021: “THE ECONOMIC BENEFITS OF IP TRANSPORT AT 400G”
[7]. Heavy Reading White Paper by STERLING PERRIN, “Converged Packet Transport for 5G”
[8]. Cisco White paper ©2021, “A Converged Network Design for Flexibility and Service Evolution”
[9]. A solution brief from SmartOptics, “The Smartoptics Guide to simpler, more flexible 100G DWDM connectivity”
[10]. ODTN introduction from https://opennetworking.org/odtn/
[11]. Andrea Campanella, OTDN Deep Dive presentation “An Open Controller for the Disaggregated Optical Network”
[12]. ONF Connect 19 ODTN Demo Video @ https://www.youtube.com/watch?v=ev6npa5vya4
[13]. Andrea Campanella (Jun 2019), ODTN Paves the Way toward Disaggregated Optical Networks
[14]. Adva Product Information, “Voyager: An open approach for Transport Switching and Routing”
[15]. VOLTHA introduction from https://opennetworking.org/voltha/

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DOI 10.17148/IJARCCE.2021.10706

[16]. Andrea Campanella (Apr, 2021), "VOLTHA 2.7 Techinar"
[17]. Arthur D. Little et. al, in Sept 2019 in AT&T article about "The central office pod – A winning cloud design"
[18]. "BAA & VOLTHA Open Source Projects" from Broadband-forum.org

BIOGRAPHY

Vishal Vasant Deshpande has received his M.S. degree from BITS, Pilani – India (specialization in Computer systems and networks) in 2001. He holds B.E. in Electronics & Telecom Engineering from Pune University - India in 1997. He has over 24 years of experience working with OEMs such as Ericsson, Cisco, Nortel, EXFO. He has managed complex Transformation program delivery for Service Providers in 4G-LTE, 5G (NSA) vEPC, ODA, Network Orchestration, Cloud VNFs for EPC. In past, he has contributed to architecture and design of OSS Platforms (e.g. Nortel Preside, Cisco Transport Manager, Ericsson OneFM, Reliance Jio OSS stack etc). He has dedicated his research efforts to SDN and Advances in Optical networking. He has published few study articles and research papers in other international journals.