**India 5G Transmission Network Requirements:**

Note : This document restricts itself to IP, Optical and SDN domain only.

**Setting Up the context**:

India is at the cusp of a digital revolution powered by increasing broadband and internet penetration, exponential data uptake, the Government’s focus on digitalisation and increasing trend of technology adoption across industries. This revolution is likely to generate new growth avenues, boost industrial productivity and has the potential to transform the socio-economic fabric of the country. In addition to 5G providing significant network performance characteristic improvements over the previous generations, it is expected to also add various service dimensions beyond the traditional voice and data through enabling technologies like Internet of Things (IoT), Artificial Intelligence (AI), Robotic Process Automation (RPA), Augmented Reality / Virtual Reality (AR/ VR) etc. giving rise to use cases across industry verticals. New business models and intermediaries are emerging in the 5G value chain to cater to the need for connectivity and for providing differentiated services to niche market segments as well as customers.

Faster speeds, higher bandwidth, lower latency. The next era of wireless technology 5G will open the door to lifechanging innovations. 5G networks will allow new innovations to flourish and dramatically change our day-to-day lives; as telecom firms spend billions on currents network and new technologies to prepare for the next era of wireless service – one that relies on dense networks of small cells. Billions of new connected devices will come online in the next decade. These devices will need to transmit significantly more data and do so reliably. Today’s wireless networks need to be enhanced to enable this connectivity.

In this Digital Revolution, Information Communication and Technology (ICT) is the dominant industry and it is the focus on broadband and impending technological shift to 5G in the sector that is expected to serve as the ‘Catalyst’.

Data speed in 5G is expected to be around 10 Gbps. With such speeds, 5G will not only provide rich user experience but also revolutionize the mobility content available online 5G network is being designed for less than 1 millisecond latency.

Hence, 5G in conjunction with IoT will be the key technology choice industries automotive, medicine, manufacturing 5G technology will fundamentally move the processing ability of handsets to mobile edge/ cloud. 5G in an Software defined Networking (SDN) / Network Function Virtualization (NFV) environment will provide services based on network slicing whereby operators will allocate network resources (slices) in line with complexity of customer requirements 5G is expected to use higher frequency bands (30-300 GHz) which will provide better capacity, bandwidth scalability and lesser interference.





Present status of Transmission Networks in India.

The present transmission network has multiple challenges due to its legacy deployments. The existing network was designed to meet the needs of prevailing technology on need basis, where in there is hardly any scope to scale up the technology or capacity.

Indian CSP deployments have museum of technologies deployed in Access, Aggregation and Core networks. While the Larger operators such as VF/AT have already migrated most of their networks to IP or IP MPLS technologies carried over 40 or 80 channels DWDM, especially in bigger towns and cities, however still array of legacy (PDH/SDH) technology deployments can be identified in smaller towns villages and spread out geographies where PDH, SDH microwave and Optical Transmission PDH/SDH equipment has been deployed. Also for POI connectivity still the E1 based SDH/PDH equipment is deployed with all the operators though the phase shift to IP has already begin through IP trunking .

CSPs are still using CS Fall over, where ever LTE network is not available for completing the voice calls. The legacy CS core switches still support E1s, which are primarily aggregated & Multiplexed over PDH/SDH MW or Optical equipment. Hence until the complete foot print of India shift to LTE, PDH/SDH equipment will remain in the networks to meet the requirements. The growth of SDH /PDH networks will be dwindling fast due to the technology shift.

Rjio has edge over competition per say they have deployed single vendor IP/MPLS network across the country to carry the Voice and Data Traffic. In order to increase the fibre capacity they have deployed high capacity DWDM equipment from vendors such as Ciena and Nokia. Hence their control over the network, for steering the traffic, is much better compared to competition.

Need for evolution of Transmission Networks: The list is ever growing, but the fundamental features which all CSPs and Enterprises are looking far are as below :

* Get away from Vendor Lock-In.
* White Goods off the shelf hardware, Open Operating system and multi vendor, multi technology vendor support. Disaggregation of Network Routers (Open echo system of Hardware, Operating system and Applications)
* Should support SDN (software defined networking).
* IP/ Optical Integration in common hardware to save cost.
* Adaptive IP with separation of control and data plane.
* IPMPLS TP/ ASON, Segment Routing, GMPLS UNI and GMPLS support.
* The Product should be cloud Native and should support multi -cloud so that the vendors can achieve Scalability , Capacity, modularity, cost savings in capex and opex, more innovation and flexibility so that vendor lock-in is not a constraint.
* Should support interfaces for facilitating 25Gb~400 Gb Ports. Flexibility in aggregating and steering traffic.
* Real time inventory visibility, with capacity utilization and insight driven live traffic steering for traffic management and DR (Disaster Recovery) .
* The Network should support Network slicing. Support possible standards by TM Forum, ETSI, MEF etc. L3, L2, EVPNs, Segment Routing, Wave length slicing, Flexible ethernet, OTN slicing, ITU-T G.MTN shall be supported.
* Network Abstraction layer should facilitate simplification and automation of Services Provisioning, Network Capacity Planning, quicker introduction of new services, coordination of multi-layer .
* Streaming, model-driven telemetry based on open standards such as Google Remote Procedure Call (gRPC) and HTTP/2 with YANG modelling enables network nodes to push out massive amounts of telemetry data in a secure and machine-friendly format.
* Automation and orchestration support with open standards. The product should support open standards such as ONL (Open Network Linux), NFV (Openstack for cloud native VM support), ONAP for automation and orchestration of Multi Vendor Mutli-Technology and Multi-Layer management. ODL, ONAP, MEF, TMF API support.
* Vendor is expected to be associated with the following groups for standards.: TIP (Telecom Infra Project), MSA (Open ROADM Multi source agreement), OCP (Open Compute Project) , ONF (Open Networking Foundation), CORD (Central office re architected as data center) , MEC (ETSI Multi Access Edge Computing), ONOS (Open Network Operating System Projects.
* SD WAN for enterprise network. Plug and Play architecture with cloud native controller to configure the policies, authenticate and securitise the networks.
* Auto Inventory update in system (Physical, Logical and Geographical) management software for easy identification.

**Insight-driven automated networking**: The Expectation of CSP and Enterprises are to have a network which is adaptive and they have full control over the network resources with real time visibility. The network should be Intelligent, agile and responsive. It should be cloud native and support multi cloud. The network should also support service protection and DDOS (Distributed denial of services).

The next wave of mission-critical, industrial-grade internet applications is even more sensitive to latency, packet loss and round-trip delays. Internet of Things (IoT) applications used in smart homes, cities and cars may not generate the same traffic volume as internet video, but they represent a considerably higher value per bit. These applications require network services that are optimized for high performance, quality and reliability.

As service providers reimagine IP networks to be increasingly responsive, secure and efficient, a more insight-driven, automated operations model is critical.

Big-data analytics, machine-learning algorithms and the power of cloud computing allow aggregation and correlation of network, cloud and application telemetry data and extraction of actionable network health and performance insights in the time required to take meaningful actions.The networks are expected to support closed loop automation and zero touch provisioning as the automation evolves.

Next generation of service routers – Should offer enhanced packet intelligence and control capabilities that go well beyond the 5-tuple IP header operations of conventional routers. These unique capabilities enable programmable network fabrics with granular traffic management, scalable flow optimization, and highly effective in-line DDoS attack mitigation.

The Service Router Operating System (SR OS) should support streaming model-driven telemetry and a broad range of open, SDN-programmable network interfaces for efficient and reliable policy deployment .

The vendor should support a real-time data intelligence and analytics platform that offers unique insights into the network infrastructure, services and consumption patterns to help identify and optimize over-the-top (OTT) content and application traffic, and deliver network forensics for real-time detection and mitigation of DDoS attacks.

To make traffic flow, the network needs connectivity and capacity. To make traffic flow without constraints or concerns requires visibility on how it flows through the network, with control to steer around obstacles as they occur, preserve network quality under load conditions and protect network services while under attack.

**DDOS Attacks (Distributed Denial of Services Attack)** :

The Router is expected to mitigate DDoS attacks by filtering DDoS traffic at the service edge and peering gateways. Volumetric DDoS attacks shall be mitigated by stateless inspection of the IP header and UDP or TCP payload. This method requires the capability to look into the packet payload for the matching signature pattern identified by the network forensics function. Matching flows can simply be dropped by these gateway routers to avoid the flows reaching and overwhelming the target of the attack.

**5G BTS Functional Split and Latency requirements** :

Before we proceed to understand the need for IP/Optical Integration, let us have a brief understanding of the new 5G base station functional split and latency requirements:

5G Introduces the concept of functional split in the radio base band processing protocol stack.

Low Latency Functional Split (Fs-LL) :
This split is mainly intended to reduce the interface bandwidth compared to CPRI. The traffic over this split is antenna traffic (constant bit rate with latency 50 micro second or lower) .

High Latency functional Split (Hs- HL) :
The split is intended to increase latency tolerance and reduce bandwidth for the interface. The traffic over this link is user traffic. The latency requirements of functional split are related to end to end end to end application latency. For 10 Ms end to end applications, a budget of 2-4 Ms is allocated to transport so that RAN edge could be placed 400 KM away from core.

Understanding the following pictures is essential as the new transport need to support the following requirements of 5G (Split, Capacity and Latency) .

**Capacity and Latency requirements with 5G** :



RAN Capacity , Spectrum and Cell size



End to End Functional Latency : The following figure illustrates the RTT (Round Trip Time) time delays during HARQ Loop ( LL-Fs – CPRI), Front Haul and Back Haul transport.



The transport network should have flexibility to deploy all combinations of deployment of C- RAN or O RAN



To support the diverse deployments vendor should have the solution (Product family) to meet the design requirements and it should be flexible, small foot print and power efficient. The Product family together should support front haul , mid haul and back haul applications. As Part of solution the product should support Packet-Optical integration platform and it should provide enhanced -Performance time and frequency distribution network as per ITU-T G.8271.1 and G.8261 standards. The Product should satisfy the stringent Timing Error (TE) requirements of OTDOA (observed time difference of arrival), using a point to point bi-directional Optical timing channel over the same optical fiber. The time and frequency information need to be transported from site to site over the Mid-haul and CRAN front haul networks with time information carried via IEEE15882v2 PTP messages. This approach will ensure variable latency and jitter of the switched data path is greatly improved .

In a 5G environment, operators need to create flexible, scalable, and dynamically reconfigurable optical networks for access, metro, and core networks. To help operators achieve this crucial goal, Vendor should offer a carrier SDN-enabled, “smart” programmable fabric that uses physical and virtualized transport components, which can be controlled with software-defined networking principles and APIs. This smart fabric provides a foundation for moving toward the next generation of mobile networks and enables secure, dynamically interconnected services.

When combining carrier SDN and NFV, the underlying transport network becomes more agile and responsive to changing requirements. Carrier SDN solutions automatically discover the network topology and build an abstracted view of it. Based on the performance and characteristics of the physical nodes, carrier SDN performs end-to-end computation and establishes an end-to-end Layer 2 VPN through the network. These connections leverage the reconfigurable optical fabric—which is based on ROADMs—to interconnect the network service access points. The connections may include either individual wavelengths or groups of wavelengths to be directed from the optical domain into the electronic domain and vice versa.

The reconfigurable optical fabric (IP/Optical integrated) should permit the flexible configuration of a direct point-to-point wavelength connectivity service between the macro site/C-RAN hub and mobile data center. It should achieve this without intermediate Optical-Electrical-Optical (OEO) conversion and bypasses any intermediate nodes, while also providing diverse path redundancy for network resiliency. Optically bypassing electrical switching nodes does not add any digital switching delay, so the optical layer offers the lowest possible delay for delay-constrained applications

**Future Mode Technology Evolution.**



**IP/Optical Integration**:

IP/optical integration is a key strategy to address both short term and strategic service provider business challenges.

In the near term, IP/optical integration removes operational and technological barriers that inflate overhead cost and impede routing and transport convergence. Service providers will more economically scale network capacity, efficiently conduct cross-domain network operations, and effortlessly monetize network assets.

For the longer term, IP/optical integration provides the agility and programmability needed for innovative control paradigms based on software defined networking (SDN). SDN further improves network utilization with on-line traffic engineering and bulk optimization to dynamically adjust capacity to fluctuating demand. SDN also enables emerging cloud service offerings such as public and private data center interconnect. For 5G network slicing and steering of traffic SDN will play a critical role as the SDN controller will have the network abstraction knowledge.

IP/optical integration addresses the disparities and disconnects at the management, control and data plane that make conventional routing and transport networks so costly and cumbersome to operate.

* Legacy transport services are statically provisioned.
* Manual intervention and elaborate workflows are typically needed to orchestrate cross-layer operations.
* Service provisioning is complex, time consuming and error prone.
* The network infrastructure is far too rigid, static and disconnected to adequately respond to fluctuating demands, or to facilitate dynamic service control.

**Evolving to a dynamic, agile and programmable network**

Service providers can leverage IP/DWDM technologies to transition from operating IP routing and optical transport in separate silos, to an integrated multi-layer deployment model with significant cost and performance synergies.

*IP/Optical control plane integration* is the most strategic aspect. It can be conducted in parallel with management and data plane integration as each plane addresses different issues and offers complementary integration benefits. The following 3 steps establish a dynamic, programmable and unified multi-layer control plane :

1. Equip the [*optical transport*](http://www.alcatel-lucent.com/solutions/agile-optical-networking/components) network with a *GMPLS control plane*. Optical Transport Network (OTN) and reconfigurable optical add-drop multiplexors (ROADMs) technology offer flexible and cost-efficient grooming and transport for IP/Ethernet and SDH/SONET payloads. *GMPLS protection and dynamic restoration* features leverage this flexibility to more efficiently protect services and improve network utilization.
2. Extend dynamic transport control capabilities to the routing layer through a *GMPLS User-Network Interface*. GMPLS UNI integration improves operational efficiencies by closing the loop between the routing and transport control planes without requiring manual intervention. It establishes a *unified multi-layer control plane* to coordinate traffic forwarding, protection and restoration in the most economical way.
3. Expose an SDN abstraction layer with *programmatic SDN application interface*. to help monetize the multi-layer network as virtualized, cloud consumable services. SDN control elements such as the path computation element ([PCE](http://www.rfc-base.org/rfc-4655.html)) help optimize capacity usage by enabling dynamic traffic engineering and bandwidth calendaring (Bandwidth on demand) .
4. Notable interfaces are OpenFlow, NETCONF, BGP-LS and the PCE Communica¬tion Protocol or PCEP (RFC 5440).

Openflow enables SDN controller to define access control lists (ACL) and do traffic steering.
Network Configuration Protocol (NET CONF) uses XML and YANG Model for configuration data.

BGP Link State (BGP-LS) liverages border gateway protocol as a source of topology information and safely distributes interior gateway protocol information to entities out side the IGP peering.

PCEP Path computation Element Communication Protocol is originally designed for offloading optimal path computation in MPLS Traffic engineering (MPLS TE) networks to path computation Element (PCE) .

PCE is a critical element for enabling dynamic network resource control. It supports dynamic path set up of multilayer infrastructure with various constraints such as bandwidth, latency and diversity and enables online Traffic engineering and optimization. It facilitates more control of networks, apply network operator policies and addresses multivendor integration considerations. Multiple PCE can exist in exist in a hierarchy and they will collaborate to compute multi domain paths.

For example : GMPLS multi layer routing engine may ask centralised PCE to assist in computing an explicit route (XRO) that takes into account specific constraints such as BW, Latency, Physical diversity etc.

PCEP (RFC 5440) defines interface between PCE and PCE clients (Network nodes, NMS etc) .

1. Integrated Transponders (IP with DWDM) will allow routers to directly plug into the DWDM layer w/o requiring an optical transponder.

Integrated Packet Optical transport in the transport system allows cost effective grooming of IP/Ethernet traffic for better fiber utilization and saves overlay router ports.

Each integration step delivers immediate cost and efficiency benefits and contributes to an open and programmable multi-layer control plane to improve service velocity and facilitate dynamic SDN control. The next three sections illustrate the benefits of this.

Dynamic protection and restoration with GMPLS

Service providers are always looking for ways to run their networks hotter and maximize returns on network investments. Conventional transport networks often reserve as much as 50% (referred to as 1+1 protection) of provisioned capacity to recover from failures. This approach is very costly and even ineffective for protecting IP traffic:

* Besides keeping up to 50% of transport capacity in reserve, backup protection paths are pre-provisioned, unable to take the actual failure location into account for re-routing options, and unable to recover from multiple failures.
* Most IP traffic can tolerate brief outages and limited packet loss. This traffic can leverage the alternate network paths instead of dedicated 1+1 protected paths.
* IP routing topologies typically have high degrees of connectivity with many alternate paths. However, 1+1 protection only supports the use of a single backup path.

State-of-the-art OTN and ROADM transport technologies can use an intelligent control plane that provides the right amount of protection for a given service class, leading to more cost-effective utilization of networks resources. These protection capabilities leverage the generalized multiprotocol label switching (GMPLS - RFC 3945) architecture. GMPLS adopts key concepts from the MPLS control plane used in IP routing with functional enhancements to support multi-layer transport networks.

GMPLS enables the transport network to dynamically route or reroute traffic around failures or on to optimal paths based on network utilization and/or service SLA constraints. The GMPLS user-network interface (UNI) interface lets routers dynamically signal transport paths with support of various service protection options.

An MPLS control plane is deployed at the routing layer, while GMPLS provides a multilayer transport control plane to control connectivity in electronic (OTN) and photonic (ROADM) equipment. The GMPLS UNI allows routers (UNI-C or Client side) to communicate with the transport devices (UNI-N or Network Side). GMPLS can be used to create protected optical segments (UNI-N to UNI-N) between transport devices. GMPLS UNI is required to create protected end-to-end generalized label switched paths (gLSPs) between routers (UNI-C to UNI-C) through the optical network.

GMPLS UNI enables crossing the administrative boundry between routing and transport, allowing the IP routing layer to directly communicate resource requirements with the underlying transport network with out manual intervention through NMS.



Dynamic restoration capabilities should be supported to enable efficient sharing of backup resources by moving from a 1+1 to a shared alternate path protection model that is also able to recover from multiple failures. As a result a considerable amount of reserved protection resources are freed up, with the remaining being used for revenue generating traffic with strict SLA criteria, allowing for more capacity for less demanding services while also offering these services high availability via alternate path based protection.

With the right architecture, GMPLS-based transport layer recovery mechanisms can be applied in combination with recovery mechanisms in the IP/MPLS layer to implement differentiated availability SLAs for different classes of service. Differentiated service availability requirements can be mapped on an appropriate multi-layer traffic protection and restoration strategy in order to balance availability, redundancy and resource utilization for the best returns on network investments.

The GMPLS suit should support routing protocol OSPF-TE, Signaling Protocol RSVP-TE and Link Management protocol LMP, standardised by Management body.

Simplify and streamline cross-domain operation with GMPLS UNI ( This need to be supported by Routers) .

Most service providers take a segregated approach to routing and transport operation, which results in a fragmented management view. This makes it:

* Cumbersome to manage connectivity between routing and transport systems
* Time consuming to correlate and isolate faults that impact multiple domains
* Labor-intensive and error-prone to orchestrate resource operations across domains
* Costly to automate operations due to the need to integrate and coordinate different protocols, information bases and processes across routing and transport devices

The GMPLS User to Networking Interface (RFC 4208) enables crossing the administrative boundary between routing and transport, allowing the IP routing layer to communicate its resource requirements to the underlying transport network without the need for operator intervention . The reverse interaction is also enabled. The transport layer can directly inform the IP routing layer about relevant events to more effectively use network resources.

Closing the loop between routing and optical transport enables a consistent use of network resources, which leads to improved network efficiency because it removes the need to touch each layer separately. It also helps to consolidate, coordinate and automate management activities across routing and transport layers with fewer touch points and less manual intervention.

Capitalizing on dynamic SDN resource control

Conventional bandwidth provisioning practices only follow the long term trend. Usage statistics over the past weeks or months are collected, aggregated and fed into off-line traffic engineering tools that estimate what capacity adjustments are required to fulfill demand for the coming weeks and months.

With statically provisioned capacity based on forecasts, service providers must err on the side of caution by over-provisioning capacity. Unexpected demand surges or traffic spikes can still lead to traffic being clipped at occasions, without opportunities to leverage or share unused capacity during off-peak hours for other tasks.

Introducing more agile capabilities that can make *periodical* adjustments to allocated capacity can tap into a number of new revenue generating opportunities that arise from bandwidth calendaring and off-peak/on-peak hour services. For example, database auditing or backup services could benefit from unused capacity during off-peak hours. The ability to make periodical adjustments to network capacity can improve network utilization, for example by utilizing the complementary peak hours of residential and commercial traffic to lower the total amount of peak capacity needed,

The ability to make even more agile and dynamic capacity changes would enable the introduction of more efficient bandwidth-on-demand and bandwidth bursting services through self-service portals, two service capabilities that are highly desired by business users. Applying SDN for dynamic load-balancing, on-line traffic engineering and bulk optimization can mitigate network hotspots and better align capacity demand and availability. A converged IP/optical network with dynamic SDN resource management can adapt to unexpected demand fluctuations with minimal capacity requirements.

The Optical Networking Product family should support GMPLS control plane with multi-layer network support. Should cover all Access Metro and Long Haul needs including reconfigurable ROADM upto 20 degrees with colourless, directionless, contention-less flex-grid (CDC-F) capabilities to carry any service over any wavelength in any direction without contention and with flexible grid spacing. The Product should support universal OTN switching fabric to groom and switch any mix of client traffic including OTH ODUk GigE, 10GigE, SDH/SONET STM 64/OC 192 and 40Gb/s, 100/200/400 Gb/s signals .

GMPLS UNI should be supported by the Edge and Core routing equipment.

**Cross Domain Multi Layer Management and SDN control**.

The Network services platform (NSP) should support
Network Optimization (Services Aware network optimization, Multi domain multi layer orchestration and Path computation) and Services Automation (Network Aware Services Placement, Network Abstraction and services Provisioning L0-L3). The NSP should be a Carrier SDN Platform that unifies service automation and network optimization for delivery of on demand network services across multiple layers , physical/Virtual infrastructures and multivendor equipment.

The IP/Optical integration strategy should leverage routing and transport technologies, platform and operations practices. This approach establishes an integrated multilayer routing and transport infrastructure with a unified control plane and Programmatic SDN support interface.

## Disaggregated Routing

Minimize vendor lock-in, ensuring competitive pricing, more choice, faster innovation, and cost-effective scaling with router disaggregation.

* Enable scalable, resilient routing with unique multi-unit stackable solutions from street cabinet to core. Carrier class white boxes for disaggregated routing and switching.
* Open and converged network operating system delivering carrier-class confidence and flexibility for IP networks for routing and switching.
* With an open disaggregated approach to routing solutions that breaks vendor lock-in and accelerates innovation. The Router/Switches Product portfolio of white box switches/routers should support 200 Gb/s to 9.6 Tb/s on standard merchant silicon to provide a cost-effective, software-centric, and flexible solution for network routing. With carrier-class features including hardware redundancy, advanced synchronization, multi-unit scaling, and temperature hardening as per the demands of carrier networks.
* Should Offer full resilience and incremental scaling with unique multi-unit concept. Should fit ideally into 5G networking with versatile synchronization capabilities.
* Key drivers for white boxes are flexibility, lower capital expenses, and reduced operating costs through network automation. White boxes contain basic mechanics along with the network processor or fabric silicon depending on their role in multi-unit scaling nodes, together enabling customization with the NOS and other software for specific use cases.
* The Vendor solutions portfolio should support smooth migration toward open and disaggregated network architectures, with a range of white box routers portfolio, Converged Network Operating System (CNOS), and intelligent control based on software-defined networking (SDN) controller and orchestration solutions.
* To meet specific carrier-grade requirements like:
* Extended memory buffer: Supporting specific routing and switching functions within transport networks
* High-performance synchronization: Institute of Electrical and Electronics Engineers (IEEE) 1588v2, Synchronous Ethernet, and robust and flexible Global Navigation Satellite System (GNSS) synchronization options
* Stacking option for incremental scaling and full redundancy. Fabric-based multi-unit stacking, also known as horizontally scalable routers (HSRs), enables horizontal scaling to achieve much greater capacity, with hundreds of Tb/s within a single managed node.
* Modularity to ensure maximum flexibility and high reliability.
* The routers should be loaded with Open Network Install Environment (ONIE), which enables the installation of a compatible NOS (network Operating System).
* Environmental hardening: Secured operation under challenging conditions
* Optimal form factor: Supporting typical telco-grade installations.
* External interfaces for alarm and synchronization: Adaptation to telco installations.
* Should support merchant switching silicon, a standard Intel processor, and a Linux operating system.



**Design requirements for Modern IP Networks for supporting 5G Applications**

**5G will drive new Network requirements in Transport ( IP)**

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With IP routing platforms should support.

* Support massive, multi-dimensional scale without compromising intelligence or performance (3.0 Tb/sec Network Processor)
* Adapt to transient conditions with real-time telemetry and insight-driven network automation
* Secure systems and data with network-integrated DDoS mitigation
* Get maximum value from your network investments with routing platforms that deliver hardware and software extensibility.
* Should support clear channel 1 Tb/s flows. It should also support flexible, high-density 10GE, 40GE, 100GE, 400GE interfaces and terabit-speed links.
* protects your network from DDoS attacks with high-scale enhanced packet intelligence and control technology. By supporting advanced deep packet lookups and flow control at scale, the platforms should support router-integrated DDoS mitigation solution.
* The New design should reduce per-gigabit power usage by more than 50 percent compared to previous generations of silicon. It should combines intelligent memory with a high degree of silicon integration to simplify board designs and shrink IP routing platform footprint.
* Should support deterministic performance under stringint traffic loads, ensuring consistent system operation no matter how QOS, ACLs, IP or MPLS capabilities and network functions are scaled.
* Should support Millions of IPV4/V6 Routing Information Base entries (RIB)
* Tens of thousands of P2P amd P2 Multi point VPNs.
* Over 5 lac residential subscribers for broadband
* Fully deterministic buffering with fine grained scalable QOS
* Upto 2 Mn ACL per router line card
* Designed for extensibility of hardware and software.
* These capabilities should be supported concurrently with out performance degradation.

**IP Based 5G era : IP Transport connecting many devices and domains.**

Operators may like to aggregate the traffic from multiple RAN nodes, FTTH nodes and other devices. The aggregation of traffic will be tiered ring structure (Access, Midhaul aggregation and back haul core aggregation rings with growing capacities) or hub architecture (Topology dependent) where operator would like to first aggregate the traffic through IP, IPMPLS or Ethernet sources and then carry it over optical transport. The following figure indicates a typical IP Transport connecting many devices…

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Most CSPs use a mix of transport technologies. This makes it critical to weave all transport options, such as microwave, optical, Ethernet/IP and broadband access, into a single network architecture that can be managed and run holistically. The evolving demands on transport networks as we move towards 5G are driving many CSPs to consolidate transport on IP networking, seamlessly weaving all network domains into one, all-IP environment.

IP networking, which is really a combination of IP, MPLS and segment routing should efficiently address many important networking dimensions, including control plane, data plane, management plane, QoS and traffic management, synchronization and security.

The IP Product should be featuring high throughput, improved port densities, high scalability, sophisticated QoS capabilities, low latency and built-in resilience. The all-IP transport layer that can sustain massive network traffic growth while supporting the efficient delivery of 5G cloud-enabled services. In addition the product to handle multiservice diversity and extend the transport benefits delivered for 5G to other services,including enterprise, residential and wireline. Product to support the following key features viz.

• **Capacity:** terabit capacity with high-speed interfaces and high-port densities, delivered in a variety of form factors and encompassing compact, extended temperature range platforms

• **Latency:** new product architectures with improved processing capabilities deliver short packet

processing times and allow for flexible deployment options (such as cost-effective transport of both low latency and bursty traffic)

• **Enhanced QoS**: improved packet processing, queuing and traffic engineering capabilities push the

boundaries of mobile broadband, helping to significantly improve the customer experience. Coupled

with multiservice capabilities, enhanced QoS becomes a foundation to build many new and enhanced use cases

• **Interconnectivity:** wide choice of protocols supported over legacy (SDH/SONET) and next-generation Ethernet interfaces (1GE/10GE/100GE)

• **Synchronization:** built-in, redundant options for GNSS, SyncE/IEEE1588v2 and BITS

• **Security:** efficient, high-bandwidth IPsec, MACsec and use of VPNs for traffic and resource isolation

• **Programmability and automation:** the portfolio should be manageable through automation and orchestration tools for multivendor , multi layer technologies, supporting open APIs and interface to SDN controllers through which CSPs can benefit from SDN-automated provisioning, optimization and assurance, their by significantly improving their ability to rapidly address changing market requirements and deliver premium broadband services.

Conclusion :

The following technologies will coexist as the existing 2G/3G/4G networks will continue to remain for few more years and 5G networks will grow in parallel. Hence the existing IP, IPML Transport portfolio has to evolve to support SDN interfaces and GMPLS – UNI. Integrated IP/Optical systems with built in SDN and GMPLS capabilities will be introduced in the network for smooth implementation of 5G services supporting scalability, agility.

**SD WAN :**

**Refer enclosed document for specifications.**

* Rajesh Sharma