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SUPPLY AND INTEGRATION OF ACTIVE NETWORK LAYER SYSTEMS

1. ACTIVE NETWORK LAYER REQUIREMENTS

RUNE Infrastructure requires Open Access Network (OAN) network based on Passive Optical Network (PON) access technology and IP/MPLS based high-speed aggregation and core network. Required architecture must be three-layer topology with Access (Active Access Node (AAN) Layer), Aggregation (Aggregation Node (AGGN) Layer), and Core (Internet Services Provider Connection Node (ISPCN) Layer), where Core acts as a service delivery point.
General Scheme of connectivity can be found in Section 8.1.

One part of the network will be implemented in Slovenia dedicated primarily to cover end users in Slovenia and another part of the network will be implemented in Croatia dedicated primarily to cover end users in Croatia. RUNE infrastructure requires high availability with two ISPCN locations in each region and many AGGN and AAN locations in each region in order to cover requested number of end users and provide their connectivity to Internet Service Providers (ISP).

The overall solution must consist of:

- Four redundant ISPCN nodes (two in Slovenia and two in Croatia);
- Five AGGN nodes in Slovenia with multiple AGGN devices, which must have redundant connection to both ISPCN nodes in Slovenia;
- Two AGGN nodes in Croatia (will be at the same location as two ISPCN nodes) and must have redundant connection to both ISPCN nodes in Croatia.
- Two AGGN nodes in Croatia must be implemented in such way that they can be moved away from the ISPCN location any time if needed;
- AGGN-ISPCN connections implemented through leased fibre/capacity over existent infrastructure and also over private fiber infrastructure;
- Several active access nodes (AAN) providing connectivity to end users and each need to have dual-home connectivity to two aggregation devices in AGGN node;
- DWDM transport network must be connecting all AGGN nodes to ISPCN nodes (unless AGGN and ISPCN are on the same location) and potentially some distant AAN locations to nearest AGGN node;
- An optical network termination implemented at the user premises.

AGGN in Slovenia will be connected to ISPCN in Slovenia only and AGGN in Croatia will be connected to ISPCN in Croatia only, where ISPCN in Slovenia and Croatia will be interconnected with dedicated high-speed link between them.

Connectivity between AGGN and ISPCN locations as well as between ISPCN locations will utilize leased optical fiber links (or leased capacities) in the first phase, where solution for this DWDM transport network must provide the most efficient use of leased or private optical fiber infrastructure. In the initial phase also the connectivity between AAN and AGGN layers will be established over leased capacities (typically 10 G pseudo-wire service).

Based on the above stated each bidder must provide a planned delivery dynamics for all network-side active equipment layers, taking into account their own proposed solutions.

Provided network solution must be 100% transparent for all ISP services and Content Providers (CP).

This infrastructure project must support multitenant environment and support different ISPs and their services.

Locations of network nodes in Slovenia and Croatia are presented in *Appendix 11 – AAN List* of the tender documentation.

There will be a need to lease transmission lines between AGGNs and ISPCNs from well-known operators (like Telekom, DARS, Stelkom), however exact transmission lines parameters of any operator are not known in advance.

Proposed solution is based on most logical assumptions and considering all necessary precautions when dealing with optical transmission lines lengths and quality.

Another assumption is that newly deployed optical fiber cables will meet the highest standards for technical specifications allowing equipment vendor to use long-haul »grey« or DWDM optics in »dark-fibre« scenarios.

General requirements for the active network layer:

- All supplied equipment must be IPv6 supported, enabled and configured;
- To implement one Interior Gateway Protocol (IGP) (ISIS or OSPF) over Slovenian and Croatian ISPCN and AGGN network nodes;
- To implement Multi Protocol Label Switching (MPLS) between all devices in ISPCN and AGGN nodes except on AAN;
- Implement L2 type of services between AGGN and AAN nodes;
- To support connectivity of any ISP to any of the ISPCN locations in RUNE network, where ISPCN locations must be the only service delivery points for ISPs and CPs;
- To support multi-homing connectivity of any Optical Line Termination (OLT) equipment to any two (at least two) AGGN locations (or two AGGN devices in the same AGGN) in the network regardless of AGGN geographical location, where all connections must support active/active and active/standby mode of operation;

- To support that an OLT is physically connected with one link to AGGN in Slovenia and another link to AGGN in Croatia, where this is required for redundancy or high availability purposes;
- OLT devices must have redundant connection from AAN to AGGN, where in the final stage, the solution must enable multiple rings, connecting each AAN with two or more AGGN nodes;
- In case of failure on any of the links between AAN and AGGN the switching time for traffic (in case of failure) must be aligned with standard <=50ms time;
- The system must support equal cost load balancing for all multi-homed OLT devices in active/active mode of operation;
- Possibility to upgrade OLT equipment to 10G XGSPON and WDM PON;
- A temperature hardened equipment is preferred at the AAN nodes, in a way to avoid the need for power supply to cooling systems in case of external power failure;
- AAN nodes are up to 80 km from the AGGN nodes (or AGGN satellite devices);
- Any AAN node may contain one or more OLT devices;
- AGGN must support connectivity of ISPCN with any AAN using different transportation networks available during network growth (leased and/or private) and enabling all possible technological connection types: Ethernet, lambda or proprietary DWDM transport solution;
- The topology must concentrate on as few active points as possible, to contain CAPEX and OPEX. Space is an issue, and so is energy consumption, cooling, uninterrupted power supply and physical security;
- Solution must provide network scalability and cost effective possible growth, where the topology of the active network must be thought in a way that new network parts can be added without the need to redesign the whole concept/topology;
- Solution must provide network redundancy for connections within the network, devices and services;
- A specific request in terms of active equipment is to give the possibility to offer VLAN in VLAN (Q-in-Q and VLAN trunks) and Jumbo frames to the end user;
- Solution must provide power autonomy with UPS at all active points for at least 12 hours;
- A “Pay-as-you-grow” solution is requested;
- Solution must provide optical network termination at the user premises;
- Equipment will be installed into communication containers in standard width 19’ racks. AC 220V is available at all active points. An UPS with at list 12 hours autonomy for the installed communication equipment and cooling is provided in an adequate communication container. -48V DC power is provided for any active equipment.

RUNE network will be built in three main phases. The offered solution must support the building of the network step by step according to the following requirements for each phase:

- Phase 1: During first phase RUNE network will require one ISPCN node in Slovenia and one ISPCN node in Croatia. In each of these ISPCN nodes one or more ISP will be connected. During this first phase AGGN nodes will be collocated with ISPCN nodes, where one ISPCN node in Slovenia will get AGGN equipment from one of the AGGN nodes in Slovenia and the traffic from 6 AAN locations in Slovenia will be connected to this AGGN equipment. Additionally one ISPCN node in Croatia will get AGGN equipment as well and the traffic from 11 AAN locations in Croatia will be connected to this AGGN equipment. Please keep in mind that equipment in these AAN locations might be connected via leased fiber or leased capacities (10GE service will be leased). All ISP services to the end users must be fully functional. Redundancy will not be required during first phase.

- Phase 2: During second phase RUNE network will require installation of second ISCPN in Slovenia as well as second ISPCN in Croatia. Additional AGGN nodes will be installed as well, where these additional AGGN nodes will be placed to their final locations and connected to their final ISPCN nodes. In Croatia final locations of AGGN nodes will be collocated with ISPCN nodes. During this second phase also additional AAN locations will be connected to AGGN nodes. All ISP services to the end users must be fully functional. Redundancy (where possible) will be required. All changes made in the network must be done without end user service interruption.
- Phase 3: During third phase RUNE network will install all AGGN equipment to its final location and connect all the remaining AAN locations to their final AGGN locations in order to provide final capacity as well as redundancy in the network. All ISP services to the end users must be fully functional. All changes made in the network must be done without end user service interruption.

1.1. CAPACITY REQUEST IN NUMBERS

Beside general requests proposed solutions must consider all the below listed information:

- Expected total end-user home connected number is 116.000 in Slovenia and 70.000,00 in Croatia (65:35 ratio), with possible home passed total end number 372.000 (address list with geolocated data for each address is published at www.ruralnetwork.eu).
- Covered number of settlements is:
  - 2.971 in Slovenia and
  - 705 in Croatia
- Customer is willing to use 90% of GPON access ports and at least 10% of XGS-PON 10G access ports. There should be:
  - At least 352 legacy GPON OLTs (AAN) with 8 GPON ports and number can rise up to 500 (a 16 port 1U device is acceptable)
  - At least 20 XGS-PON OLT with 4 GPON ports systems inside the network and number can rise up to 35
- Customer must provide minimal 100 Mb/s downstream connectivity for following European Digital Agenda via legacy GPON and even more in case of XGS-PON to end-user
- In case of 1:64 GPON split ratio resulting in worst case traffic scenario end-user connection speed should be 39 Mb/s

- Each GPON OLT in final configuration must be connected to AGGN node over two connections (either twice to the same AGGN or to two different AGGNs) and having both uplinks active.

1.2. REDUNDANCY AND RESILIENCY OF THE PROPOSED SYSTEM

There are different requests for redundancy; therefor solution should achieve redundancy with the following elements (in final situation):

- Path redundancy
    - Connection between all ISPCN nodes is done via two geographically independent fibre connections;
    - Connection between ISPCN and each AGGN node is done via two geographically independent fibre connections;
    - Connection between AGGN and each AAN node device is done via two geographically independent fibre connections;
    - There is no path redundancy between AAN node and end-user CPE equipment.
- Device redundancy
    - There are redundant routing devices in ISPCN node;
    - There are redundant routing devices in AGGN node;
    - There is no redundant routing device (switch) in AAN node.
- Routing engine redundancy
    - Routing device in ISPCN node has redundant routing engine with unified ISSU;
    - Routing device in AGGN node has redundant routing engine or redundant VM routing engine and need to have unified ISSU;
    - There is no redundant routing engine in AAN node.
- Active device power redundancy
    - Routing device in ISPCN node has redundant hot-swappable power supply;
    - Routing device in AGGN node has redundant hot-swappable power supply;
    - Routing device (switch) in AAN node has redundant power feeds.
- Active device cooling redundancy
    - Routing devices in ISPCN and AGGN node have hot-swappable fans;
    - L2 device (switch) in AAN node has resilient multi-fan design for maintaining the system temperature with one fan failure.
- UPS/power redundancy
    - There are redundant power supply options in ISPCN and AGGN nodes.
- Optical transmitter redundancy
- Management system redundancy
    - Management services need to be redundant between both countries.

Network resiliency is requested in any network layer.

- ITU G.8032 ERPS, and 802.3AD/802.1AX protocols are protocols between AAN and AGGN nodes

- Service protection is requested within IP-MPLS network, two EVC or two LSPs are requested among two UNI interfaces
- MPLS FRR is requested within IP-MPLS network

1.3. COMMON ISPCN AND AGGN REQUIREMENTS

ISPCN and AGGN network must:

- Provide enough connection capacities to redundantly aggregate network traffic/data from all AGGN nodes;
- Provide enough scalability and must be able to grow as the number of users grow;
- Have enough processing capacities to handle all the possible traffic (incoming, outgoing);
- Have enough connection capacities for:
    - Redundant connections in case of redundant core nodes (Slovenia, Croatia);
    - Connecting ISP and CP (even redundantly);
    - Connection to its management servers located in ISPCN locally;
    - Connection to service servers in case of L3 network setup;
- ISPCN network must be ready for all now known future needs, applications and standards;
- Unpredicted network growth in case of faster user/traffic growth then predicted shouldn't and must not have any impact on network core from any technical aspect;
- Pay as you grow Feature/Functional expansion
    - End customer services to be distributed across the AGGN device nodes for scaling and turn/on/off on a per subscriber basis;
    - L3 features/functionality on a per subscriber basis;
- Synch Input/output - Any Data Port can accept PTP or SynchE.

The key features required at the AGGN and ISPCN layer include:

- High-density Ethernet Links Aggregation from access layer;
- Non-blocking and low latency forwarding of the transit traffic to ISPCN segment;
- Perform EVC stitching to provide continuous End-to-End layer 2 EVC;
- Perform S-VLAN normalization;
- OAM and network resiliency features;
- Inline timing and synchronization support for voice and TDM applications;
- Support for versatile Layer 2 Carrier Ethernet and Layer 3 Services over MPLS:
    - Performing of Layer 2 EVC to Layer 3 Service stitching.

The following protocols must be supported on any routing device in AGGN and ISPCN layer:

- ISIS, OSPF/OSPFv3, BGP and BGP RR, RSVP, LDP, Segment routing;
- IP/MPLS (L3) services:
    - EVPN, VPLS, L3VPN, PWE3, NG-MVPN;

    - P2MP LSP (mLDP and RSVP EVPN-MPLS);
- L2 services:
    - MPLS-over-GRE;
    - VXLAN;
    - GRE;
- Bridge Port Extension (802.1BR);
- High Availability:
    - Redundant Routing engine;
    - NSR;
    - ISSU;
    - GRES;
    - BFD;
- Metro Ethernet:
    - Support for OAM features;
    - Must be MEF CE 2.0 certified on designed networks speeds (10G and 100G);
- Precision time protocols (PTP):
    - IEEE 1588 and SyncE;
- PCEs (Path Computation Elements).

Price erosion over next 5 years for the laser interfaces >= 10G is of most importance.

1.4. ISPCN CENTRAL LOCATION EQUIPMENT REQUIREMENT

All ports in ISPCN nodes connecting devices transporting user data traffic (except ports to ISP and management devices) must be 100Gbps point to point.

ISPCN must provide interconnection between all AGGN within the region and interconnection to ISPCN between Slovenia and Croatia. All ISPCN locations must be a single point of entry for ISPs. ISPCN must provide equipment for NMS and other services requested. High availability is requested in ISPCN nodes. Management system will be implemented in one ISPCN location.

ISPCN node must be implemented with a minimum of two separate Core Routing Devices (CD) to provide High Availability and providing connectivity to end user data traffic devices as well as for all NMS, OSS/BSS, and other network services equipment proposed. Connectivity from AGGN to ISPCN (Core) routing devices in each ISPCN must be full line speed.

High Availability from AAN to ISPCN will be provided by L3 routing protocols, based on IGP protocols ISIS, OSPF, and Segment Routing (SPRING) with MPLS services signalled via BGP. Basic MPLS services will be E-VPN and NG-MVPN. For management and some other specific services L3VPN will be used as well.
IPv4 and IPv6 must be supported through complete network, as well for all Wholesale services. ISPCN (Core) and Aggregation network must also support PTP (Precisions Time Protocol). Each routing device must have a redundant routing engine with unified ISSU and redundant power supply and be SDN ready. Routing engine of each

routing device should be able to forward at least 4.8 Tbps of traffic passing through the device.

Basic features, which must be supported by all ISCPN devices

- Cost Optimized 100GE Router;
- 10M FIB, 80M RIB, 1M MAC;
- Feature rich core (including RSVP-TE, LDP, SR, SRv6 ready, Timing, and Multicast), Firewall filters & filter terms;
- L2/L3 services at scale (EVPN, VPLS, EOAM);
- Intelligent DDoS with FlexFilter, BGP Flowspec v4/v6, EPE;
- uRPF, Filter-based GRE encap & decap, VLAN tag manipulation;
- Segment Routing, SR/RSVP interop, TE++, SyncE/PTP timing, BGP-LU FRR, MPLS over UDP, NG-MVPN, BIER, SRv6 ready;
- BIER, Flex Filters, Telemetry, Hybrid PTP Timing;
- Class B Mask profile, Inline MACSEC, Granular Flow sampling, Inline video monitoring;
- MEF 2.0 certified.

Price erosion over next 5 years for the laser interfaces >= 10G is of most importance.

1.5. AGGN LOCATION AGGREGATION EQUIPMENT REQUIREMENT

All ports in AGGN nodes connecting devices transporting user data traffic (except ports to OLT) must be 100Gbps.

All the functionality must be provided in the redundant way with high availability in mind. Each AGGN device must be connected to all ISPCN locations in region (Slovenia or Croatia accordingly).

For the aggregation layer (not access and/or core), the tenderer will accept also an "infrastructure-as-a-service" offers, provided that sufficient initial capacities are assured, and future upgrades are in-line with the needs expressed in this document.
Extensions of the network (possibility to add AGGN nodes) to nearby areas need to be foreseen. Redundancy between the AAN nodes has to be planned (at least two connections from each AAN node, to two AGGN nodes, using multichassis LAG or other similar mechanism), but can be fully implemented only after the initial phases due to the current topology of the network. OLT connections to any two geographically dispersed AGGN locations might be requested and these two AGGN locations might be in different countries (Slovenia and Croatia).

Carrier grade aggregation switches (MEF certified) are required, supporting multiple 100G Ethernet connections with link trunking / bonding capacity, with IP-MPLS functionality, and possibility of direct use of WDM SFP+ interfaces. All necessary interfaces must be the building block of the aggregation network.

To achieve the appropriate aggregation of AANs in each AGGN a routing devices must be used. Each AGGN node must be implemented with at least two Aggregation Devices (AD) within the same AGGN location.

Independent management connection to every device within AGGN node is planned via switches and mobile routers with backup 2G/3G/4G connections. Secure out-of-the-band connection via VPN to the management system is strictly required.

AGGN capacity (routing, switching) must be scalable, node capacity upgrade (adding new devices, ports, slots or optical connections into existing node) must be possible without the need to interrupt services for existing connections.

Basic features, which must be supported by all AGGN devices

- Metro Ethernet Features:
    - EOAM: LFM, CCM, Y.1731 (LM, DM, SLM), RFC2544 (Reflection and Generation);
    - E-LINE (PWE, QinQ, EVPN-FXC), E-LINE (VPLS, EVPN, Bridging), E-ACCESS, E-TREE;
    - G.8032v1/v2;
    - IP/MPLS (v4/v6), Global Multicast, VRRP, IRB;
    - ISSU, SyncE/PTP timing;
    - MEF 2.0 certified.

A more detailed list of features to be delivered is included in PAT and FAT protocols, which are Appendix 9 and Appendix 10 respectively of this tender documentation.
Price erosion over next 5 years for the laser interfaces >= 10G is of most importance.

1.6. AAN LOCATION ACCESS EQUIPMENT REQUIREMENT

GPON active equipment with multilayer splitting to a maximum ratio of 1:128 (1:64 accepted). A wire-speed connectivity between AANs and the aggregation network is a must. This means that the sum of nominal capacity of all access ports of an AAN must be provided also towards the aggregation nodes (Non-blocking hardware design, except malfunctions). AAN are equal or less than 80 km from the AGGN node.

Each OLT device must support at least two connections to AGGN node where these two or more connections might be to the same AGGN or to any two different AGGN locations regardless of the geographical location or country (Slovenia or Croatia).

AAN node presents one or more OLT devices, where each OLT should have at least 2 upstream (10GE or 40GE/100GE) ports and 4, 8 or 16 downstream ports – PON ports depend of type of PON device.

AAN node must have dual-homed connection towards 2 access ports in 2 different Aggregation Devices (AD) and in some cases to 2 different geographical AGGN nodes (which can be in the same country or even in different countries). GPON OLT device need to have two (2) 10GE ports, XGS-PON OLT device should have at least four (4) 10GE ports or 100GE ports as an upgrade option.

ITU-T standard PON technology - GPON (ITU-T G.984) and XGS-PON (ITU G.9807.1, 2016) is required.

AAN need to support all major L2 features including QinQ, IGMPv2 and IGMPv3, MAC Bridges, DHCP Relay Agent and service classification based per port, S-VLAN-ID, C-VLAN-ID and p-bit.

The access layer consists of the AAN, which are typically deployed in vicinity of the customer devices and enterprise customer premises. Therefore, protocols for user access and connectivity to upstream aggregation routers are needed. The key requirements for the access layer are:

- Provide connectivity for customer equipment on the physical port—user network interface (UNI);
- One UNI connects one subscriber device, which is Layer 3 CPE;
- Enable Ethernet Virtual Connection (EVC) towards the remote UNI and establish OAM control plane on a per EVC basis;
- Bundle customer CVLAN and map it to EVC connection;
- Multiplex multiple EVCs on a single UNI;
- Apply network service attributes;
- Properly designed performance and bandwidth to meet growing service needs;
- Allow for Residential and business services
    - CE services for Business with OAM and HQOS to deliver Business Class SLA and Carrier Ethernet (MEF) conform services;
    - L2/L3 residential CPE to deliver residential services;
- Integrated remote diagnostics to reduce troubleshooting times and on-site visits
    - Integrated Videocontent Analyzer to analyse MPEG over IP/Multicast;
    - Tcpdump;
    - Integrated Wireshark network analysis for realtime debug.

A more detailed list of features to be delivered is included in FAT and PAT protocols.

The solution must foresee the possibility to be upgraded to 10G PON at the AAN. For such scenario, a Coexistent element should be offered (according to Access Network Scheme in section 4.12.) Coexistent element is situated in AAN/POP. It must be 19", 1RU, modular. The scheme of active components of the network from content source to the end user is attached as well.

Supported protocols:

- Zero bandwidth impact during switch fail over;
- In Service Software Upgrades (ISSU);
- IP service-aware architecture to ensure optimal bandwidth efficiency and guaranteed instant channel changes;

- Software that enables IMS integration and expands existing IP service-aware features such as IGMP multicasting, VLAN tagging and stacking, and security features;
- Security and service segmentations features:
  - DHCP snoop/proxy;
  - IP Source Guard/Source verify;
  - PPPOEiA and PPPOE profiles;
  - MAC Forced Forwarding
    - to ensure DHCP/PPP and MAC/ARP table integrity and avoid IP/MAC and gateway spoofing;
  - IGMP V2 and V3;
  - IGMP snoop/proxy;
  - MVR (Multicast Vlan Registration) to optimize IPTV delivery;
  - IPv4 and IPv6 Access Control Lists;
- 2.5 Gbps / 1.25 Gbps PON downstream/upstream speeds as minimum per each access port, ITU-T G.984 compliant, including G.984.7;
- at least 10% user ports must be 10G PON (NG-PON2 recommended, XGS-PON minimum);
- at least 4x1 GE and 1x10 GE symmetrical lines, MEF certified, must be available for end-user services on each OLT;
- Wire-speed uplink interface from OLT to aggregation nodes;
- Voice services with SIP or H.248 signalling;
- Video services via IPTV;
- Dynamic Bandwidth Allocation (DBA) and HQoS;
- 128-BIT Advanced Encryption Standard (AES);
- VLAN in VLAN (or Q-Q or VLAN trunking);
- IP-MPLS (can be done with different active equipment at user side;
- G.8032V2 Ring support to facilitate ring topologies of the access nodes;
- LAG (active-active/active-standby) support on the access node in case of P2P connection.

Optical power calculation:
Optical power budget is to be calculated as ~0.4 dB/km @ 1310nm, split (N*3.5 dB for a split of 2N) & other losses (connectors, insertion losses, etc.).

Inputs for power calculation of the access network:
- Quality of used optical components (uniform distribution, low insertion loss);
- Use of connectorised (type 0.5 dB loss) connections;
- Use of class C+ laser interfaces or stronger (32 dB optical power budget) in the access network;
- Multi stage splitting (typical 1:4 followed by 1:16);
- A 15km cable (fibre ITU-T G.657A1 or better) length limit is imposed for the construction of the primary passive access network. Maximum 2km of secondary (last mile) line is to be calculated.

Small form factor OLT's (preferred is 1RU/2RU height), with a modular, redundant architecture and temperature hardened are desired to meet our space requirements/constrains. Temperature hardened reduces the requirement of air conditioning/cooling in remote POPs.

OLT must provide possibility to mix and match all line card types in a common single chassis (GPON and XGS PON cards) or in separate 1U devices.

The number of GPON ports will grow with the network. At least 8 port GPON blades should be offered. Upstream interfaces should be included in the offer. User side GPON interfaces must be SFP type (removable) and should be quoted per unit. Minimum order quantity and delivery times must be expressed.

1.7. CONNECTIVITY BETWEEN NODES

As there will be a lease of transmission lines between AGGNs and ISPCNs, line parameters of operators are not yet known. Proposed solution must be based on most logical assumptions and considering all necessary precautions when dealing with optical transmission lines lengths and quality.

Another assumption is that newly deployed optical fiber cables will meet the highest standards for technical specifications allowing equipment vendor to use long-haul »grey« or DWDM optics in »dark-fibre« scenarios.

Connectivity between AGGN and ISPCN locations as well as between ISPCN locations will utilize leased optical fiber links and potentially private optical fiber. Solution for this transport network must provide the most efficient use of leased or private optical fiber infrastructure, where standard 40ch DWDM equipment is required utilizing at least 100Gbps capacity per wavelength in order to provide efficient use of bandwidth, where 200Gbps and 400Gbps wavelengths must be supported for future growth. Provided DWDM equipment must support 50GHz standard ITU channel spacing.

Due to possibility of extending the distance between end nodes additional intermediate amplifier locations between end nodes must be supported.

Due to better resistance to dispersion and possible lower quality of optical fiber links coherent technology is required.

All connections must be redundant using at least two data paths between each two connected nodes (AGGN to ISPCN or ISPCN to ISPCN).

DWDM transport equipment must support Optical Supervisory Channel (OSC) for separated management purpose as well as redundant power supply.

Assumptions based on worst-case scenario:
According to network topology and provided schemes there are 16 optical links with maximum distance of 110km required between AGGN nodes and ISPCN nodes, where 2 links connecting the most distant AGGN in Slovenia will need to pass through one

of the AGGN nodes which is closer to ISPCN and will not be directly connected to ISPCN in Slovenia. Additionally, there are 2 optical links connecting ISPCN nodes between Slovenia and Croatia, where maximum distance of 200km is planned with intermediate point possible in case intermediate site is required for amplification purposes. The distance of 110km takes into account optical fiber used, where 28dB loss is expected on the optical fiber link. The distance of 200km takes into account optical fiber used, where 50dB loss is expected on the optical fiber link and intermediate location is available in case network design requires additional amplification to be used. This intermediate location is in a temperature-controlled environment and with power supply being available.

At least one of the connections between AGGN and ISPCN will be less then 120km, but there will be a need to provide intermediate passive OADM in order to connect AAN location to AGGN location via DWDM infrastructure and not directly via private fiber link like all other AAN locations. Please provide a calculation what is the maximum distance between AGGN and ISPCN in case such passive OADM is inserted. Keep in mind that OADM must be passive as there is no power supply at this location. This intermediate location is outdoor manhole, where temperature hardened equipment must be considered.
As both AGGN and ISPCN locations in Croatia are collocated, there is no need to provide two times DWDM connectivity in final phase of the project between these two AGGN in Croatia and ISPCN in Croatia. ISPCN locations in Slovenia and ISPCN locations in Croatia are still interconnected via DWDM connectivity, where in first phase just one DWDM link will be required and in final phase redundant DWDM connectivity will be required (two DWDM links between ISPCN in Slovenia and Croatia). But there is a need to connect two distant AAN areas in Croatia via DWDM toward AGGN nodes in Croatia instead. The distance (in both cases) will be at maximum 110km and takes into account optical fiber used, where 28dB loss is expected on the optical fiber link toward both distant AAN areas. In case AGGN in Croatia will be separated from ISPCN and moved closer to AAN locations, then this same two DWDM links will be connecting AGGN in Croatia to ISPCN in Croatia instead.

There will be a grey fiber between DWDM and Active equipment. All Connections from active equipment to DWDM transport equipment must be 100GE.

Each connection (optical fiber link) between AGGN and ISPCN requires minimum capacity for 2x 100Gbps wavelengths with possibility to upgrade up to 8x 100Gbps of capacity per connection. Each connection (optical fiber link) between ISPCN in Slovenia and ISPCN in Croatia requires minimum capacity for 2x 100Gbps wavelengths with possibility to upgrade up to 8x 100Gbps of capacity per connection. Capacity upgrade must be possible without existing service interruption.
At least one AGGN location having two connections (optical links) to ISPCN location must have a minimum of 3x 100Gbps wavelengths per connection with possibility to upgrade up to 8x 100Gbps of capacity per connection.

DWDM transport equipment must provide redundancy in all levels where service between two locations might be interrupted because of link failure or DWDM equipment failure. Data traffic in AGGN node sent to two redundant connections (optical fiber links) via DWDM transport must be passed through different transponder modules/cards as well as different filters (MUX/DEMUX/OADM/ROADM) in order to provide redundancy on the transponder/filter level.

Within the AGGN and ISPCN nodes connections to DWDM system will be implemented using AOC cables or short-range 100GE QSFP28 grey 100 Gbit/s modules.

DWDM transport equipment must support NMS with Multi-Layer Service Management and Centralized SDN API access. Additional notification services (including network events like creation, deletion, attribute value change) for topology, node, and connection/connectivity must be supported. Support for alarm monitoring (for communication, equipment, environmental, security) must be available.

1.8. EQUIPMENT AT THE PASSIVE DISTRIBUTION AGGREGATION NODE (PAN)

No active parts are meant to be present in the street cabinets. Only the connectorized (LC/APC) first or second level splitters are to be installed there. Splitters will be provided by RUNE.

1.9. USER SIDE ACTIVE EQUIPMENT

ONT should have at least 1 x 1GE Ethernet ports, ideally 2 x 1 GE (at least 1x10GE, 1x1GE for XGS-PON users).
ONTs shall support 'any service any port' supporting data/voice and video services on all ports, to allow for a flexible service delivery architecture.
The price for GPON ONT, XGS-PON ONT and the price erosion for this equipment over the next three or five years is of most importance.
Extended warranty (repair or substitution) is requested for this equipment.

The offer must foresee the supply of user-side active equipment according to the following dynamics:

- At least 10 % XGS-PON ONT, max. 90 % G-PON ONT
- Total quantity of ONT foreseen is 186,000
- Quarter 4 2019 delivery max 900 G-PON ONT and at least 100 XGS-PON ONT, the rest equally distributed among the quarters of the next 3-year period
- Microdynamics of the delivery might vary according to the prospected delivery plan, as specified in the Agreement and its Appendices.

Any offers proposing a 100% XGSPON access solution with the 3-year-average ONT price (taking into account price erosion and delivery dynamics) of 52 EUR/per piece or less will be preferred over other offers. In case of such offers RUNE is willing to commit to purchasing at least 100 000 ONTs in the 3-year period.

2. NETWORK SERVICES REQUIREMENT

Network equipment must support the following services:

- IGP protocols: ISIS and OSPF;
- Overlaying protocols: MPLS, RDP, Segment Routing (SPRING), EVPN, L3VPN, NG Mcast VPN;
- Signalization protocol in AGGN and ISPCN: BGP only;
- QoS is required for end user data traffic optimisation;
- All protocols are required in Slovenia and Croatia region.

Infrastructure must be ready for the following services:

- Layer 2 transparent bitstream must be possible throughout the network (with network segmentation at aggregation level);
- Layer 3 IP-Stream services must be possible;
- Higher layer services (IP-MPLS or similar, Data Center Interconnect, 5G backhauling) must be possible throughout the network;
- IP layer services must be built in (IPv4 and IPv6) the network core.

3. NETWORK MANAGEMENT/VISIBILITY/PROVISIONING (AUTOMATION) REQUIREMENTS

One or more Network Management platforms must work with management applications to simplify and automate configuration and management of core and aggregation network's switching and routing devices as well as optical transport devices. As part of whole system the platform provides fault, configuration, accounting, performance, and security management capability, support for new devices and new software releases, a task-specific user interface, and northbound APIs for integration with other network management systems (NMS) or operations/business support systems (OSS/BSS).

Unified approach is required to manage a ISPCN and AGGN network infrastructure and design and deploy new services. Centralized management and orchestration of network devices and services need to be brought through a unified display for real-time visibility.

Network Management platform should have ability to extend to third parties through RESTful APIs. Its functionalities have to be accessed through a GUI that uses workflows per-user and progressive disclosure to enable operator-centric and scope-specific visibility and control. Its ability must support and cover the most important transport network capabilities:

- Design, provisioning, activation, and validation of RSVP-signalled label-switched paths (LSPs);
- Design, provisioning, activation, and validation of L2/L3 VPNs across MPLS and Carrier Ethernet networks;
- Design and provisioning of quality-of-service (QoS) profiles for services;

- Service troubleshooting, service statistics, and performance measurement using the ITU Y.1731 specification;
- Chassis views for configuration and services monitoring ;
- RESTful-based API should allow network providers to completely automate service provisioning and effectively position their networks for future SDN and Network Functions Virtualization (NFV) architectures.

All network elements and subsystems must be fully manageable and supervised via central single-point allowing also for transparent monitoring and alerting.
All management systems must be fully redundant across the entire network including Slovenian and Croatian part.

All devices transporting user data traffic in AGGN and ISPCN nodes must support visibility through telemetry interface preferably open standard. Telemetry must be implemented in hardware in order to push information out of the interface toward management station. Visibility of the active equipment and interfaces in AGGN and ISPCN must be provided through fabric, where each active device must support telemetry or OpenConfig standard. Each active device in AGGN and ISPCN must support collection of real time flow information in order to provide visibility and potential automation.

There will be a single management point for the whole network. RUNE network management system must provide logging for all system events from network devices locally.

All necessary equipment must be offered, to ensure reliable and possibly automatic provisioning.

The proposed equipment shall be ready to support migration to SDN/NFV. Ideally with native Netconf/Yang implementation and Open Flow support for future ASN/NFV to eliminate a proxy/middleware layer. Native Netconf/Yang shall cover both provisioning and alarm/messaging. The operating system of the OLT shall be of modular nature, and identical across the proposed OLT systems. In Service Software Upgrade is desired. Please highlight the supported/tested SDN platforms and embedded support tools (MPEG analyzer, Wireshark, Python diagnostics scripts,…)

Management system should support well-documented northbound interface API's. Preferred via the industry standard REST/JSON.

The Network Management system should support:

- Network and Service configuration when the product is both online & offline including device pre-configuration;
- Software upgrades;
- Status requests and command automation;
- Statistics and performance data collection;
- Alarm and event collection.

Optical network management system (NMS) must be possible to be used as a standalone NMS system or as a "domain controller" inside a full SDN architecture.

Network management system of optical transport system should have the following functionalities and capabilities:

- Alarm surveillance;
- Geographical view of the nodes and view of network elements;
- Management of connections (Path set-up and routing);
- Performance Monitoring;
- Logs.

Following standardized interfaces for SDN the architecture should be supporting:

- Southbound interface:
    - RESTconf with ONF Yang model for management of the devices;
- Northbound interface:
    - RESTconf with ONF T-API (Transport API).

Redundant in-band and out-of-band management connection to any device in the designed AGGN and ISPCN network is required. Secure connections for authorized administrators from the public Internet need to be terminated on Next Generation Firewall with IPSec / SSL capabilities. Next Generation Firewall for remote access is installed in every ISPCN node. Routing protocols enable availability of any network resource inside AAN, AAGN and ISPCN nodes.

Two "VPN" redundant routers are installed in every ISPCN and AGGN node for enabling secure connectivity between ISPCN management networks and AGGN management networks. Two redundant logical connections should be available between ISPCN and AGGN management networks, one via private optical network and another via public Internet or via LTE cellular network.

Out-of-band L2/L3 gigabit switch is needed to connect to any management port of network devices inside the ISPCN and AGGN nodes. Also PoE capabilities are needed to power video surveillance devices and any other PoE powered device.

Another L2/L3 gigabit switch is needed to connect all AAN management devices in the same zone via gigabit optical link. L2/L3 device is requested on each AAN with optical gigabit uplink to AAGN node.

4. END USER ACCESS MANAGEMENT

An end-user access environment includes various components – end-user access technologies and authentication protocols.

The end-user access technologies include DHCP, DNS server and authentication, authorization, and accounting (AAA) protocols, offered by the RADIUS server. End-user policy enforcement must be applied.

DHCP and DNS service in optical access networks provide IP address configuration and service provisioning.

Single point of DHCP service control should be in a datacentre. Address assignment pools are defined, from which to allocate end-user addresses. Dynamic address assignment and static address assignment of IP addresses from pre-defined address assignment pools is possible.

Above-mentioned services are necessary to enable RUNE offered captive portal.
Captive portal is a web page, where end-user is given different infrastructure status information. Captive portal offers end-user the choice between different service and content providers.
End-user access management services need to be integrated with the database of existing end-user subscriptions. Integration into Operational Support Systems (OSS) and Business Support Systems (BSS) has to be done as well.

5. ENERGY EFFICIENCY

Please, include in the offer the calculations of the energy needs for all equipment (content source, main aggregation, etc...).

The offer for active equipment should be for all the needed components to allow RUNE to become a network infrastructure provider including the necessary PSUs and 12 hours UPS for access and aggregation nodes.

The offer for active equipment should be for all the needed components to allow RUNE to become a network infrastructure provider including the necessary PSUs and 12 hours UPS

6. TESTING PROCEDURES

RUNE network will be implemented in several phases and after each phase there will be set of Partial Acceptance Tests (PAT) and Final Acceptance Tests (FAT).

During PAT functionality of network subsystems is tested, which however does not represent actual full system functionality and network performance.
During FAT full overall system functionality and capacity is tested and confirmed.
Each phase will be have its own set of activities included in PAT and FAT.

7. MAINTENANCE PROCEDURES

Maintenance procedures define system changes, which include software and hardware upgrades and changes.

Rune will provide maintenance schedule where maintenance hours will be defined.

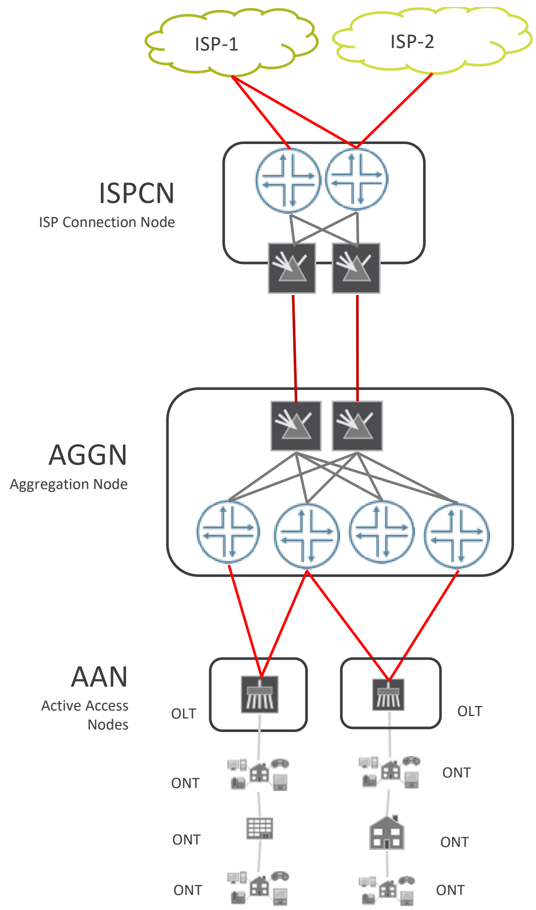
For ISPCN and AGGN nodes maintenance In Service Software Upgrade (ISSU) functionality must be supported as described in the Redundancy section of this document.

In case of Network Management Systems failure normal RUNE network operation with current configuration must not be interrupted.

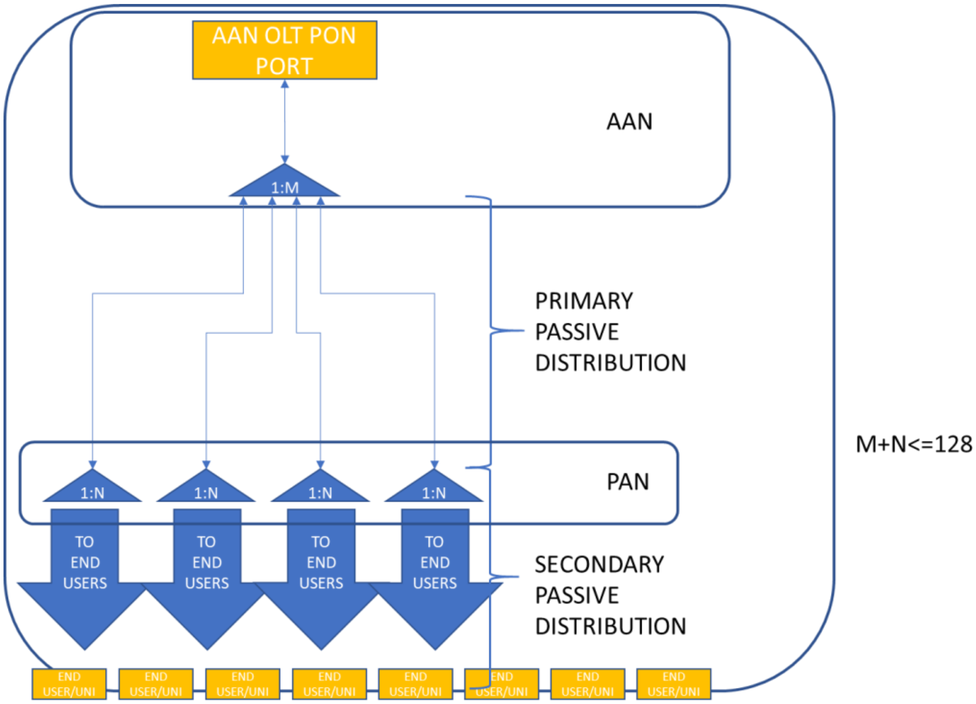
OAM features defined by Metro Ethernet Forum (MEF) 2.0 need to be established in order to provide fault management and performance monitoring.

8. SCHEMES

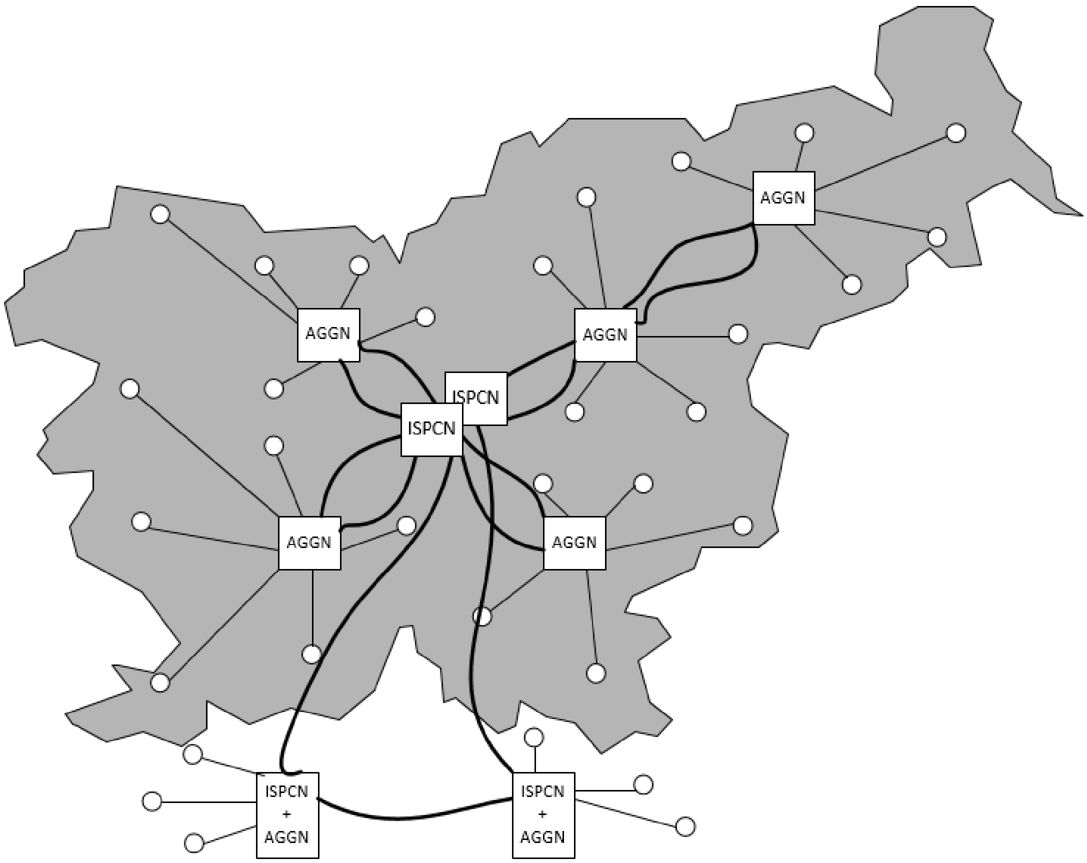
8.1. GENERAL SCHEME OF CONNECTIVITY



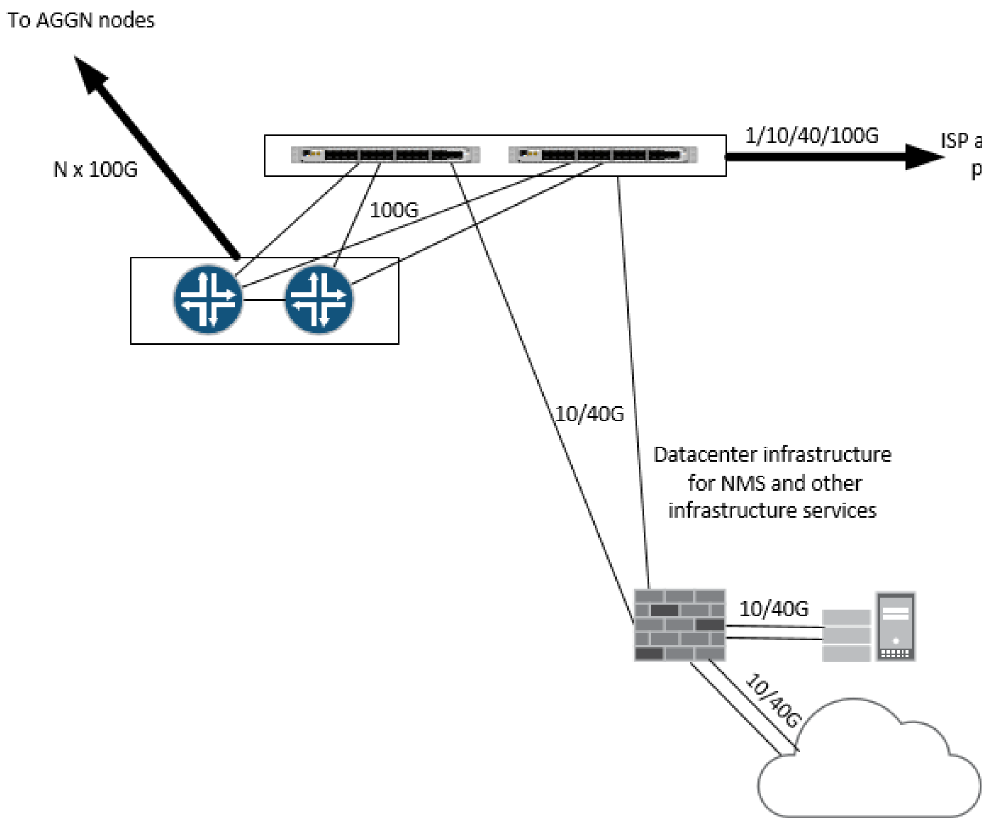
8.2. ACCESS NETWORK SCHEME



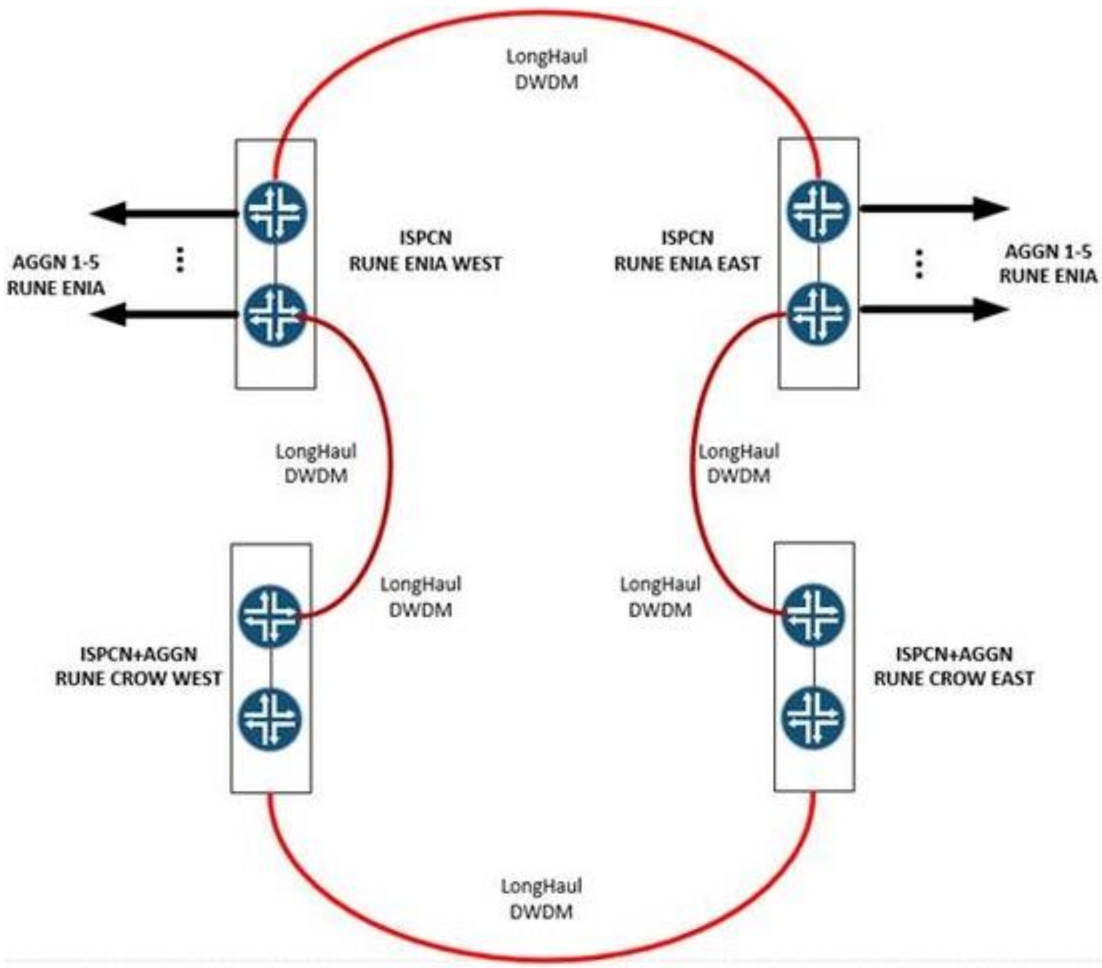
8.3. NETWORK TOPOLOGY



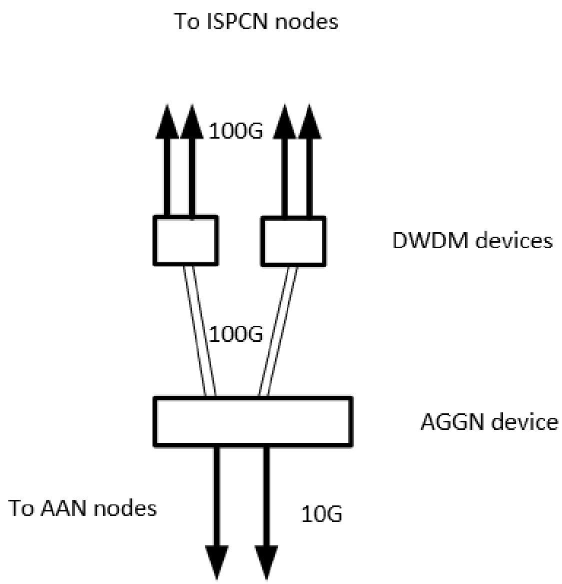
8.4. ISPCN NETWORK SCHEME



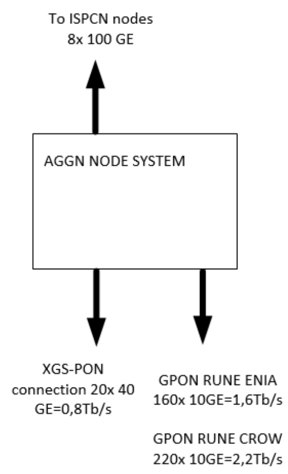
8.5. ISPCN INTERCONNECT SCHEME



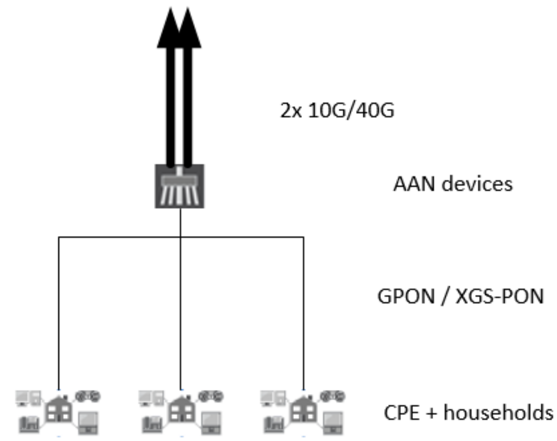
8.6. AGGN NODE INTERCONNECTIVITY FOR DEVICES



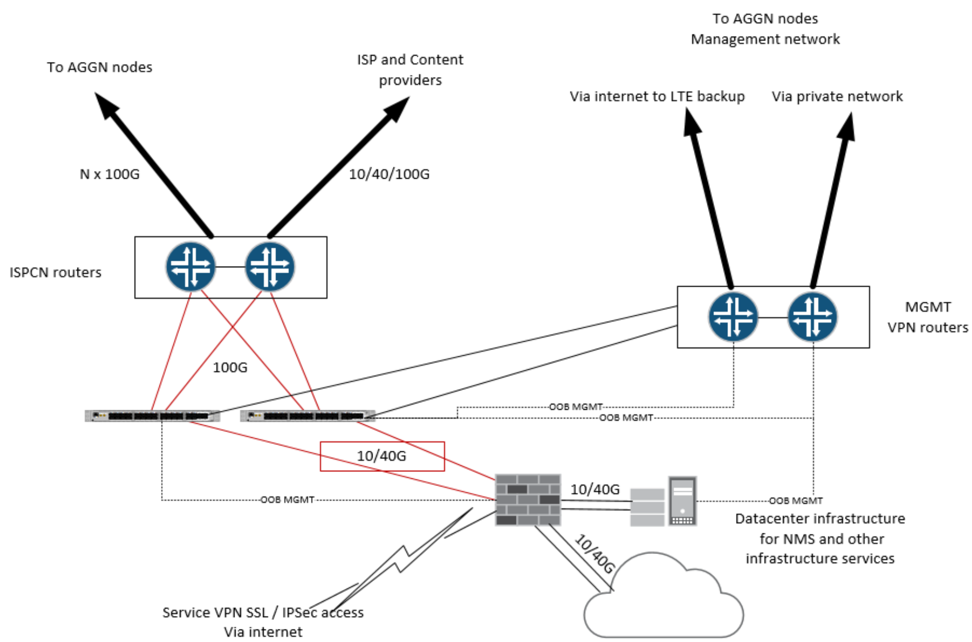
8.7. AGGN NODE THROUGHPUT



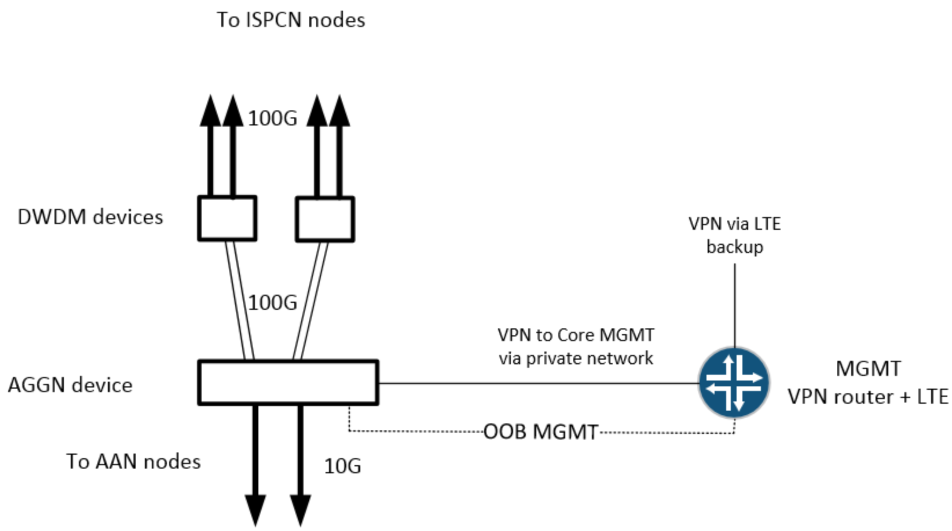
8.8. AAN INTERCONNECT



8.9. MANAGEMENT NETWORK ISPCN NODE



8.10 MANAGEMENT NETWORK AGGN AND AAN NODES



8.11 ACCESS NETWORK SCHEME