Link aggregation/bonding and load balancing with SAF products

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1. About LAG in Ethernet terminology

Link aggregation, load balancing, link bonding is computer networking umbrella terms to describe various methods of aggregating multiple network connections in parallel links to increase throughput beyond what a single connection could sustain, and to provide redundancy in case one of the links fails.

From the network point of view the link bonding is a single physical channel. Link bonding is Layer 1 aggregation of frames, which for Layer 2 is delivered as a single physical link, whereas Ethernet aggregation (mostly Layer 2) and load balancing (Layer 3) are methods for combining two or more Ethernet paths.

**Link bonding** – a Layer 1 aggregation is based on frame or bit aggregation. The best solution as any can be used in any type of Ethernet network.

**Link aggregation** – a Layer 2 aggregation is based on IEEE 802.3ad with MAC address hashing, where some implantations also allow Layer 3 aggregation based on hashing of IP address/ports.

**Load balancing** – is traffic segmentation based on pre-defined traffic path configuration, which usually is implemented in routers or Layer 3 switches. Traffic segmentation can be defined by VLANs, IP addresses, ports, etc depending on option in the device. Also load balancing can be applied on Layer 2 switches based on pre-defined paths per VLAN.

CFIP Lumina, PhoeniX and Marathon supports built-in Ethernet link aggregation, which is a microwave industry specific implementation. SAF Tehnika has designed proprietary microwave Ethernet link aggregation mechanism. It was designed along the guidelines of the 802.3ad and our mechanism complies with provisions of it, while the main enhancement specifically for microwave radio link aggregation is proprietary control protocol, which takes into account specific properties of microwave link: e.g. link capacity, received signal level, radial MSE, LDPC stress etc.

Integra and Integra S support link bonding which aggregates to both link capacity utilizing single Ethernet connection, e.g. one MAC to MAC and IP to IP.
2. Link aggregation types with SAF products

- **Built-in link aggregation:**
  
  - CFIP Phoenix M 2+0 has link bonding method which can do the link aggregation with one pair of MAC addresses. CFIP Phoenix M 2+0 aggregation is based on modem level frame aggregation (link bonding).
  
  - With Integra or Integra S – you can setup 2+0 using link bonding, using various interconnection schemes, please refer to Installation Manual.
  
  - With CFIP Lumina - you can setup 2+0 configuration using pair of four port (at least) external switches and these switches are not involved in link aggregation.
  
  - With CFIP PhoeniX/Marathon – you can setup 2+0, 3+0 and 4+0 configuration and basic external switches are required for interconnecting management traffic.
  
  - With CFIP-106/108 FODU and SAF Freemile you can setup load balancing only with external equipment, where load balancing is configured in the external switch.

- **Link aggregation/balancing using external equipment:**
  
  - With CFIP Lumina - you can setup n+0 configuration using external switches with (at least) five ports.
  
  - With Integra, Integra S, Integra W and Integra WS - you can setup n+0 configuration using external switches/routers with (at least) three/five ports (depends on desired LAG method).
  
  - With CFIP PhoeniX/Marathon – you can setup n+0 configuration using external switches with (at least) three/five ports (depends on desired LAG method).
  
  - With CFIP-106/108 FODU and SAF Freemile you can setup n+0 with external switches but this will be load balancing not link aggregation.
3. Table of aggregation types available with SAF products

<table>
<thead>
<tr>
<th>Product name</th>
<th>Aggregation type</th>
<th></th>
<th></th>
<th>Internal</th>
<th>External</th>
<th>Internal</th>
<th>External</th>
<th>Internal</th>
<th>External</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Layer 1</td>
<td>Layer 2</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Internal</td>
<td>External</td>
<td>Internal</td>
<td>External</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integra and Integra S</td>
<td></td>
<td>X</td>
<td>*</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integra W and Integra WS</td>
<td></td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFIP Lumina 2 LAN ports</td>
<td></td>
<td>-</td>
<td>*</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFIP Lumina 1 LAN port</td>
<td></td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFIP Phoenix M</td>
<td></td>
<td>X</td>
<td>*</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFIP PhoenixX</td>
<td></td>
<td>-</td>
<td>*</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFIP Marathon</td>
<td></td>
<td>-</td>
<td>*</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAF Freemile 17/24</td>
<td></td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAF Freemile 5.8GE</td>
<td></td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Layer 1 - link bonding, any devices (router, switch, PC) can be connected;
Layer 2 - link aggregation like LACP or load balancing by VLANs. Available with Layer 2 and Layer 3 switches
Layer 3 - load balancing IP based. Available with routers and some Layer 3 switches.
* - rare option, in most case is not used in Layer 2, 3 switches or routers.

Also there are another types of load balancing or aggregation based on higher layers of OSI.
4. Options and considerations for link aggregation

a. Antennas, couplers, OMT, branching system

A coupler/splitter is a passive device for dividing microwave signal, which allows combining signal of one radio into single path. The microwave signal can be divided into various proportions, for example 1:6 (asymmetrical), 3:3 (symmetrical).

An OMT or Orthomode transducer is a passive device for filtering polarization from/to circular waveguide path.

Standard SAF radio adapted coupler and OMT can be used for connecting 4 radios to a single antenna.

<table>
<thead>
<tr>
<th>Standard OMT+coupler</th>
<th>Compact hybrid combiner OMT+coupler</th>
</tr>
</thead>
</table>

Outdoor Branching Unit

Multiple radios can be connected to antenna by using circulators and filters, which can be either indoor (for all-indoor application) or outdoor. Frequency channel branching system can allow connecting multiple radios to single antenna with minimal attenuation.
Comparison for various attenuations:

<table>
<thead>
<tr>
<th>Solution</th>
<th>Attenuation per port</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMT</td>
<td>~ 0.5dBm</td>
</tr>
<tr>
<td>Symmetrical 3dB coupler</td>
<td>~ 3.5 dBm</td>
</tr>
<tr>
<td>Asymmetrical 6dB coupler</td>
<td>Port1: ~1.8dBm, Port2: ~7.2 dBm</td>
</tr>
<tr>
<td>OBU</td>
<td>~ 1.5 dBm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Total attenuation with OBU, per radio</th>
<th>Total attenuation with coupler, per radio</th>
</tr>
</thead>
<tbody>
<tr>
<td>4+0 in single polarization</td>
<td>~ 1.5 dBm per radio</td>
<td>~ 7 dBm</td>
</tr>
<tr>
<td>4+0 with dual pol antenna</td>
<td>~ 1 dBm per radio</td>
<td>~ 3.5 dBm</td>
</tr>
</tbody>
</table>

Connection via flexible waveguide

Alternatively, a 4+0 system can be attached to any dual-polarization antenna with standard flanges by using external stand-alone couplers and waveguides.
b. Capacity and link options

In many cases the target capacity is 1Gbps, which is built from multiple parallel links. Below is a table for option of achieving close to 1Gbps capacity with CFIP PhoeniX equipment.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Total capacity</th>
<th>Total BW</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>3+0 at 56MHz 256QAM strong FEC</td>
<td>3x 334 = 1002 Mbps</td>
<td>168 MHz</td>
<td></td>
</tr>
<tr>
<td>4+0 at 56MHz 64QAM strong FEC</td>
<td>4x 241 = 964 Mbps</td>
<td>224 MHz</td>
<td>Best system gain for longer distances or smaller antennas</td>
</tr>
<tr>
<td>4+0 at 40MHz 256QAM weak FEC</td>
<td>4x 248 = 992 Mbps</td>
<td>160 MHz</td>
<td></td>
</tr>
<tr>
<td>4+0 at 50MHz 128QAM strong FEC</td>
<td>4x 249 = 996 Mbps</td>
<td>200 MHz</td>
<td></td>
</tr>
<tr>
<td>4+0 at 56MHz 256QAM weak FEC</td>
<td>4x 360 = 1440 Mbps</td>
<td>224 MHz</td>
<td></td>
</tr>
</tbody>
</table>

With CFIP PhoeniX M system there is possibility to built radio links with mixed payload.

**Example capacities with Integra**

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Total capacity</th>
<th>Total BW</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2+0 at 60MHz 1024QAM Integra/Integra-S</td>
<td>2x 474 = 948 Mbps</td>
<td>120MHz</td>
<td></td>
</tr>
<tr>
<td>2+0 at 80MHz 256QAM Integra-W/Integra-WS</td>
<td>2x 514 = 1028 Mbps</td>
<td>160MHz</td>
<td>Very high system gain for link budget at 1Gbps</td>
</tr>
</tbody>
</table>
5. Built-in configuration examples

5.1 CFIP Lumina:

With CFIP Lumina link aggregation in 2+0 mode allows utilizing up to 732 Mbps Ethernet Layer 2 throughput (256QAM @ 56MHz) by using independent frequency pair for each link. Link aggregation 2+0 traffic distribution between two links is based upon source and destination MAC addresses of Ethernet packets. Link aggregation (2+0) requires multiple MAC to MAC address pair connections as path for each connection is chosen based upon Ethernet frame's source and destination MAC addresses. A sufficient diversity of MAC addresses is required to achieve maximum aggregate throughput.

CFIP Lumina 2+0 link aggregation features link and power redundancy. If link loses synchronization or any unit fails traffic will be rerouted to the active link.

Necessary equipment:

- Two CFIP Lumina links. Each CFIP Lumina FODU should have two Ethernet ports (optical or electrical)
- Two Gigabit Ethernet switches with at least 4 ports.
- In order to connect radios to single antenna you can use coupler or OMT. Alternatively you can use two separate antennas.

Fig.1 Interconnection scheme for Lumina 2+0

FODU1 and FODU2 are in the master link. FODU3 and FODU4 are in the slave link.

Features:

- Up to 732 Mbps
• Physical layer protection:
  - Protection of hardware failure
  - Radio protection
  - Modem protection
  - Ethernet protection

• Automatic reconfiguration to 1+0 (traffic rerouting) in case of:
  - Synchronization loss of master link
  - Synchronization loss of slave link
  - Hardware failure of any CFIP Lumina FODU
  - Power supply failure
  - Cable failure (link loss)

• Average switchover time 100ms

If modulation of one link is downshifted, modulation on other link will be aligned to the same configuration.

5.2 CFIP PhoeniX:

With CFIP Phoenix built-in link aggregation in 2+0, 3+0 and 4+0 modes allows utilizing up to 1Gbps Ethernet Layer 2 throughput (256QAM @ 56MHz) by using independent frequency pair for each link. An aggregation method is the same as CFIP Lumina except following:
  - Hardware failure of any CFIP PhoeniX IDU
  - Power supply failure
  - Cable failure (link loss)

Optionally there’s available CFIP PhoeniX IDU with power protection port (P/N S0GIP*11), which provides redundancy of internal power board, external power supply or power cables.

Necessary equipment:

• From four up to eight CFIP Phoenix IDU/ODU pairs.
• Two Gigabit Ethernet switches with at least 4 ports.
• In order to connect radios to antenna or antennas you can use OMT or/and couplers.
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Fig. 2 Interconnection scheme for CFIP PhoeniX 2+0
IDU1 and IDU2 are in the master link. IDU3 and IDU4 are in the slave link.

Fig. 3 Interconnection scheme for CFIP PhoeniX 4+0
IDU1 and IDU2 are in the master link. All other links are slave links.
5.3 Sample configuration with CFIP Phoenix M

With CFIP ODU adapted mounting and hybrid combiner. A hybrid combiner consists of built-in OMT with couplers attached to each polarization.

![Diagram of sample configuration with CFIP Phoenix M](image)

- **CFIP Phoenix M IDU**: 2 pcs
- **CFIP Phoenix ODU**: 4 pcs
- **Dual pol Antenna**: 1 pcs
- **Hybrid combiner**: 1 pcs

5.4 Integra, Integra S

Integra/Integra-S 2+0 aggregation (link bonding) provides ACM-aware binding of user available capacities of two parallel links each using individual frequency pair. Traffic is split per-frame over two links on modem level.

⚠️ Aggregation is not based on MAC-MAC connections. Single MAC address (e.g. router) can be used.

If any (master or slave) link synchronization goes down, switching to working link is hitless. Two Integra or Integra-S FODUs are required. In case of Integra-S OMT, dual-polarized antenna or coupler can be used.

**Necessary equipment for Integra 2+0**

1. 4 Integra/Integra-S FODUs – 2 low side, 2 high side
2. 2 or 4 SFP modules and appropriate FO cables (multi-mode or single mode) for Integra interconnection (depending on chosen interconnection scheme)
3. Electrical or optical Ethernet cables for user traffic (depending on chosen interconnection scheme)
4. In case of Integra-S – additionally 4 antennas or 2 antennas and OMT/couplers
Interconnection schemes

There are 4 possible interconnection schemes:

**Scheme 1**

1. Optical fiber cable between LAN2 (optical) ports on both units. Mandatory in all 4 schemes.

2. Electrical Ethernet cable (1000Base-T) between PoE injector’s (#1) DATA+PWR port and LAN1 (electrical) port of Slave Integra/Integra-S FODU. Both data and power are carried, therefore total length of cables #2, #3 and #4 combined should not exceed 100m.

3. Electrical Ethernet cable (1000Base-T) between PoE injector’s (#2) DATA+PWR port and LAN1 (electrical) port of Master Integra/Integra-S FODU. Both data and power are carried, therefore total length of cables #2, #3 and #4 combined should not exceed 100m.

4. Electrical Ethernet cable (1000Base-T) between PoE injectors’ (#1 and #2) DATA ports. Provides management access to Slave Integra/Integra-S FODU. Total length of cables #2, #3 and #4 combined should not exceed 100m.

5. Optical fiber cable between LAN3 (optical) port of Master or Slave Integra/Integra-S FODU and CPE for both traffic and management traffic.

**Advantages:**

- External switch not required;
- Length of optical cable for traffic/management up to 10km.
Scheme 2

1. Optical fiber cable between LAN2 (optical) ports on both units. Mandatory in all 4 schemes.
2. Cable for powering Slave Integra/Integra-S FODU. You can use 2-wire power cable with DC power adapter (P/N D0ACPW01) or standard Ethernet cable with PoE injector. Depending on power consumption cable length can be extended up to 700m. Refer to chapter RJ-45 port for details.
3. Electrical Ethernet cable (1000Base-T) between PoE injector’s (#2) DATA+PWR port and LAN1 (electrical) port of Master Integra/Integra-S FODU. Both data and power are carried, therefore total length of cables #3 and #5 combined should not exceed 100m.
4. Optical fiber cable between LAN3 (optical) ports on both units. Provides management access to Slave Integra/Integra-S FODU.
5. Electrical Ethernet cable (1000Base-T) between PoE injector’s (#1 or #2) DATA port and CPE or both traffic and management traffic. Total length of cables #3 and #5 combined should not exceed 100m.

Advantages: external switch not required; optical cables used only for interconnection between both Integra/Integra-S FODUs; only two cables installed between Integra/Integra-S FODUs and indoor facility.
Scheme 3

1. Optical fiber cable between LAN2 (optical) ports on both units. Mandatory in all 4 schemes.
2. Cable for powering Slave Integra/Integra-S FODU. You can use 2-wire power cable with DC power adapter (P/N D0ACPW01) or standard Ethernet cable with PoE injector. Depending on power consumption cable length can be extended up to 700m. Refer to chapter RJ-45 port for details.
3. Cable for powering Master Integra/Integra-S FODU. You can use 2-wire power cable with DC power adapter (P/N D0ACPW01) or standard Ethernet cable with PoE injector. Depending on power consumption cable length can be extended up to 700m. Refer to chapter RJ-45 port for details.
4. Optical fiber cable between LAN3 (optical) port of Slave Integra/Integra-S FODU and external switch. Provides management access to Slave Integra/Integra-S FODU.
5. Electrical Ethernet cable (1000Base-T) between external switch and CPE for both traffic and management traffic.
6. Optical fiber cable between LAN3 (optical) port of Master Integra/Integra-S FODU and external switch for both traffic and management traffic.

Advantages: Solution provides greatest cable length for powering Integra/Integra-S and length of optical cable for traffic/management can be up to 10km. For details on power cable length refer to chapter RJ-45 port.
Scheme 4

1. Optical fiber cable between LAN2 (optical) ports on both units. Mandatory in all 4 schemes.

2. Electrical Ethernet cable (1000Base-T) between PoE injector’s (#1) DATA+PWR port and LAN1 (electrical) port of Slave Integra/Integra-S FODU. Both data and power are carried, therefore total length of cables #2 and #6 combined should not exceed 100m.

3. Electrical Ethernet cable (1000Base-T) between PoE injector’s (#2) DATA+PWR port and LAN1 (electrical) port of Master Integra/Integra-S FODU. Both data and power are carried, therefore total length of cables #3 and #4 combined should not exceed 100m.

4. Electrical Ethernet cable (1000Base-T) between PoE injector’s (#1) DATA port and external switch. Total length of cables #3 and #4 combined should not exceed 100m.

5. Electrical Ethernet cable (1000Base-T) between external switch and CPE or both traffic and management traffic.

6. Electrical Ethernet cable (1000Base-T) between PoE injector’s (#2) DATA port and external switch. Total length of cables #2 and #6 combined should not exceed 100m.

Advantages: only single optical fiber cable required; only two cables installed between Integra/Integra-S FODUs and indoor facility.
6. Link aggregation using external equipment

Some network operators would like to use own link aggregation methods based on LACP and other methods. Most frequently ignored issue is related to putting CFIP management inside one of two balanced Ethernet paths. This is violation because balancing logic does not expect any Ethernet device in-between two aggregated switches. As a result traffic will go through but management access to each CFIP Lumina will be available only from 50% of MAC addresses – might be available from one PC but not available from another and it is absolutely not predictable.

We would like to explain some examples showing how to implement link aggregation or load balance using external switches and routers and ensure stable management access to CFIP products.

6.1 Link aggregation using external switches via LACP (or PAgP) protocol with MAC or IP address hashing on CISCO switches.

After switch CRC hash calculation based on chosen method SA-DA, SA or DA switch will send packet using one or other path. Along with traffic CFIP management packet can be routed to other branch where requested CFIP unit doesn’t exist and this may cause inaccessibility of CFIP management. To avoid this problem we recommend using two port CFIP Lumina or CFIP PhoeniX where you can separate data traffic from management traffic using VLANs.

Below is interconnection example for 2+0 Lumina with 2 Ethernet ports and external managed switches.

![Interconnection scheme for Lumina 2+0 external aggregation with switches](image-url)
In this setup we have used 2-port (electrical) Lumina and CISCO 2950 switches. Each CFIP Lumina is configured to trunk traffic on LAN port number 4 and Lumina radios management is on LAN port number 3.

![Fig.5 VLAN configuration on Lumina](image)

Note: Traffic is tagged on external switches. VLAN100 is management and VLAN200 is data traffic. VLAN0 (or VLAN1, depended on CFIP firmware) will pass untagged traffic which is required for communication between external switches. Also you can use Lumina radios built-in switch to tag Ethernet traffic (data and management traffic).

In such configuration it is important to configure CISCO switches properly. As configuration is the same on all four units and management VLAN is trunked via CFIP Lumina WAN port and external switches, this will cause network loop on management VLAN. Spanning tree will block (PVST – CISCO proprietary protocol) one of four ports to avoid network loop and management still will be accessible on all four units. Other switches are using MSTP protocol to avoid Ethernet loops with Multiple VLANs (configuration for MSTP is described below).

Another important thing is to use tools for monitoring status of Ethernet link. CISCO switches feature “Unidirectional Link Detection (UDLD)” protocol. Normally CISCO switches do not expect that on opposite side there will be Lumina which has Ethernet port and CISCO will send traffic to other CISCO even in case of signal loss between peers because Ethernet ports on Lumina and on CISCO still will be in "UP" state.
UDLD can detect broken link even if Ethernet port is “UP”, shut down it and all traffic will be redirected to another branch. Aggregation restoring is more or less depended on external switches in case of radio sync loss.

UDLD is disabled by default. You can configure it globally or on specific interface. In our configuration we have enabled UDLD globally.

CFIP Lumina, Marathon and Phoenix products have "Link State Propagation" feature which can shutdown the Ethernet port in case of sync loss.

**Configuration of CISCO switches:**

```
! errdisable recovery cause udld
errdisable recovery interval 30
udld enable
!
spanning-tree mode pvst
no spanning-tree optimize bpdu transmission
spanning-tree extend system-id
!
interface Port-channel1
  switchport trunk allowed vlan 200
  flowcontrol send on
!
interface FastEthernet0/1
  switchport trunk allowed vlan 200
  channel-group 1 mode active
!
interface FastEthernet0/2
  switchport trunk allowed vlan 200
  channel-group 1 mode active
!
interface FastEthernet0/3
  switchport access vlan 200
  switchport mode access
!
interface FastEthernet0/4
  switchport access vlan 100
  switchport mode access
!
interface FastEthernet0/5
  switchport trunk allowed vlan 100
  switchport mode trunk
!
interface FastEthernet0/6
  switchport trunk allowed vlan 100
  switchport mode trunk
!
```

**Explanation:**

`udld enable` - enable the UDLD protocol globally
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errdisable recovery cause udld – enable the timer to automatically recover from the UDLD error-disabled state
errdisable recovery interval 30 – the recovery time interval to bring the interface out of the error-disabled. 30 seconds is minimal number.
interface Port-channel1 – Specifies EtherChannel number

Interfaces Fa0/1 - 0/2 are used to trunk aggregated traffic to other peer thru Lumina radios.
Interface Fa0/3 – is network cloud (lots of SA-DA MACs)
Interface Fa0/4 – is for management PC
Interfaces Fa0/5 – 0/6 are used to trunk management data to Lumina.

There is no limitation to number of aggregated parallel links it depends on opportunity of external switches.

The same configuration of Lumina radios and switches will be in case of link aggregation based on IP hashing. You need to add "port-channel load-balance src-dst-ip" in to CISCO global configuration.

6.2 Link aggregation using external switches via LACP protocol with MSTP enabled on external switch.

By default CISCO switches are using proprietary PVST protocol. This protocol works very well without special “fine tuning” of STP. Other brands have MSTP (Multiple Spanning-Tree protocol) protocol which requires “fine tune” for correct STP behavior.
Important peculiar properties are: you need to setup region name and revision, instances per VLAN, BPDU filter must be applied on aggregated port (not physical interface), correct port priority and path costs for aggregated ports.

Configuration of MSTP:

```
spanning-tree mode mst  <- Spanning-tree mode MSTP
no spanning-tree optimize bpdu transmission
spanning-tree extend system-id

spanning-tree mst configuration
name REGION <- name for MST region, revision is 0 by default
instance 1 vlan 100 <- Instance for management VLAN
instance 2 vlan 200 <- Instance for traffic VLAN
```

Instance 0 (MST00) is enabled by default. This instance contains all untagged service packets for correct communication between external switches.

Configuration of aggregation interface:
interface Port-channel1  <- Etherchannel interface (LAG)
switchport trunk allowed vlan 200  <- Command to allow only traffic VLAN
switchport mode trunk
flowcontrol send off
spanning-tree bpdufilter enable  <- Command to enable BPDU filter
spanning-tree port-priority 0  <- Command to set port priority for Etherchannel interface (0 - highest)

Please check status of STP after successful configuration, aggregation port must be in “forwarding” state.

You need to check STP behavior on the external switches after correct configuration. Aggregation port must be in “forwarding” state.

6.3 Load balancing based on per packet or per destination using routers

Another method is to use routers and load balancing between nodes. On CISCO routers there are two ways:

- **per-packet** - load balancing allows the router to send data packets over successive equal-cost paths without regard to individual destination hosts or user sessions. Path utilization is good, but packets destined for a given destination host might take different paths and might arrive out of order.
- **per-destination** - load balancing allows the router to use multiple, equal-cost paths to achieve load sharing. Packets for a given source-destination host pair are guaranteed to take the same path, even if multiple, equal-cost paths are available. Traffic for different source-destination host pairs tend to take different paths.

We will explain the “per-packet” method which can be used to load balance with one source IP and destination IP.
Fig. 6 This is interconnection example for 2+0 Lumina with one or two Ethernet ports and CISCO routers.
Configuration of CISCO routers:

Router Nr.1:

```
! ip cef
ip cef load-sharing algorithm original!
interface FastEthernet0/0
  ip address 192.168.20.2 255.255.255.0
  ip load-sharing per-packet
duplex auto
  speed auto!
interface FastEthernet0/1
  ip address 192.168.30.2 255.255.255.0
  ip load-sharing per-packet
duplex auto
  speed auto!
interface FastEthernet0/1/0
  switchport access vlan 20
! interface Vlan20
  ip address 192.168.205.1 255.255.255.0!
  !
ip route 0.0.0.0 0.0.0.0 FastEthernet0/0 192.168.20.1
ip route 0.0.0.0 0.0.0.0 FastEthernet0/1 192.168.30.1
ip route 192.168.205.0 255.255.255.0 FastEthernet0/0 192.168.20.1
ip route 192.168.205.0 255.255.255.0 FastEthernet0/1 192.168.30.1
ip route 192.168.205.0 255.255.255.0 Vlan20!
```

Router Nr.2:

```
! ip cef
ip cef load-sharing algorithm original!
! interface FastEthernet0/0
  !
ip address 192.168.20.1 255.255.255.0
  ip load-sharing per-packet
duplex auto
  speed auto!
interface FastEthernet0/1
  ip address 192.168.30.1 255.255.255.0
  ip load-sharing per-packet
duplex auto
  speed auto!
interface FastEthernet0/0/1
```
CEF switching (Layer3) requires higher performance of equipment than Layer2 link aggregation methods. Please check the CISCO routers CEF performance by this URL:

6.4 Load balancing based on VLANs with protection

Load balancing with VLANs can be configured on any CFIP device or Integra S/W with one Ethernet port and any switch which has VLANs and Spanning-tree per VLAN (PVST, MSTP). Load balance provides also protection in case of one link fail.

```plaintext
switchport access vlan 20
!
interface Vlan20
  ip address 192.168.206.1 255.255.255.0
  !
ip route 0.0.0.0 0.0.0.0 FastEthernet0/0 192.168.20.2
ip route 0.0.0.0 0.0.0.0 FastEthernet0/1 192.168.30.2
ip route 192.168.206.0 255.255.255.0 FastEthernet0/0 192.168.20.2
ip route 192.168.206.0 255.255.255.0 FastEthernet0/1 192.168.30.2
ip route 192.168.206.0 255.255.255.0 Vlan20
!
CEF switching (Layer3) requires higher performance of equipment than Layer2 link aggregation methods. Please check the CISCO routers CEF performance by this URL:

6.4 Load balancing based on VLANs with protection

Load balancing with VLANs can be configured on any CFIP device or Integra S/W with one Ethernet port and any switch which has VLANs and Spanning-tree per VLAN (PVST, MSTP). Load balance provides also protection in case of one link fail.

```
spanning-tree vlan 200 port-priority 0 <- port priority for VLAN 200

Interface Fa0/1 - port for management PC
Interface Fa0/13 – port where traffic is already tagged with VLANs 200,300
Interface Fa0/17 – port to CFIP device with management and traffic VLANs
Interface Fa0/18 – port to CFIP device with management and traffic VLANs

VLAN 200 will be blocked on interface Fa0/17 and VLAN will be blocked on interface Fa0/18 by STP in such configuration. VLAN 300 will pass through link “1” and VLAN 200 will pass through link “2”. Also management VLAN will be blocked to avoid loop and all CFIP devices will be accessible.
6.5 Link aggregation using CISCO switches and LACP (or PgAP) aggregation method with Integra S radios.

After CISCO switch CRC hash calculation based on chosen method SA-DA, SA or DA (or IPs) switch will send packet using one or other physical port which is included in Port-Channel interface (virtual interface which contains bunch on physical interfaces). Along with traffic Integra S management packet can be routed to one or other branch where requested radio unit doesn’t exist and this may cause inaccessibility of radio’s management. To avoid this problem we recommend using two ports of radios where you can separate data traffic from management traffic using VLANs.

For example: PoE ports (electrical) at each radio will be used for device management with power only and LAN2 (fiber ports) will be used as LACP ports.

As all management ports will be connected to the same broadcast domain Ethernet loop will occur. To avoid loop STP will block one of management port in CISCO switch, if STP is enabled. Which port will be disabled depends on STP configuration. Of course it is not necessary to connect all management ports to CISCO, but it will add protection to the management in case if one (or more) unit failure.

Note: Ethernet loop will not occur on LACP (Port-Channel) ports.
Logical scheme and CISCO (ME3400) configuration example

Switch A configuration and status output:

```
interface Port-channel1
  port-type nni
!
interface GigabitEthernet0/1
  port-type nni
  switchport trunk allowed vlan 200
  switchport mode trunk
  media-type rj45
!
interface GigabitEthernet0/2
  port-type nni
  switchport trunk allowed vlan 200
  switchport mode trunk
  media-type rj45
!
interface GigabitEthernet0/3
  port-type nni
  channel-group 1 mode active
!
interface GigabitEthernet0/4
  port-type nni
  channel-group 1 mode active
!
two1-Main#show spanning-tree

VLAN0001
  Spanning tree enabled protocol rstp
  Root ID  Priority    32769
```
Address     108c.cf8d.7800
Cost        3
Port        56 (Port-channel1)
Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

Bridge ID  Priority  32769  (priority 32768 sys-id-ext 1)
Address     108c.cf8d.8700
Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time  300 sec

<table>
<thead>
<tr>
<th>Interface</th>
<th>Role</th>
<th>Sts</th>
<th>Cost</th>
<th>Prio.Nbr</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Po1</td>
<td>Root</td>
<td>FWD</td>
<td>3</td>
<td>128.56</td>
<td>P2p</td>
</tr>
</tbody>
</table>

VLAN0200
Spanning tree enabled protocol rstp
Root ID  Priority  32968
Address     108c.cf8d.7800
Cost        4
Port        1 (GigabitEthernet0/1)
Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

Bridge ID  Priority  32968  (priority 32768 sys-id-ext 200)
Address     108c.cf8d.8700
Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time  300 sec

<table>
<thead>
<tr>
<th>Interface</th>
<th>Role</th>
<th>Sts</th>
<th>Cost</th>
<th>Prio.Nbr</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gi0/1</td>
<td>Root</td>
<td>FWD</td>
<td>3</td>
<td>128.1</td>
<td>P2p</td>
</tr>
<tr>
<td>Gi0/2</td>
<td>Altn</td>
<td>BLK</td>
<td>4</td>
<td>128.2</td>
<td>P2p</td>
</tr>
</tbody>
</table>

tw01-Main#show lacp neighbor
Flags:  S = Device is requesting Slow LACPDUs
        F = Device is requesting Fast LACPDUs
        A = Device is in Active mode       P = Device is in Passive mode

Channel group 1 neighbors

<table>
<thead>
<tr>
<th>Port</th>
<th>Flags</th>
<th>Priority</th>
<th>Dev ID</th>
<th>Age</th>
<th>Key</th>
<th>Key</th>
<th>Number</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gi0/3</td>
<td>SA</td>
<td>32768</td>
<td>108c.cf8d.7800</td>
<td>12s</td>
<td>0x0</td>
<td>0x1</td>
<td>0x104</td>
<td>0x3D</td>
</tr>
<tr>
<td>Gi0/4</td>
<td>SA</td>
<td>32768</td>
<td>108c.cf8d.7800</td>
<td>20s</td>
<td>0x0</td>
<td>0x1</td>
<td>0x105</td>
<td>0x3D</td>
</tr>
</tbody>
</table>

Switch configuration and status output:

interface Port-channel1
port-type nni
!
interface GigabitEthernet0/1
port-type nni
switchport trunk allowed vlan 200
switchport mode trunk
media-type rj45

Link aggregation/bonding and load balancing with SAF products
```bash
! interface GigabitEthernet0/2
  port-type nni
  switchport trunk allowed vlan 200
  switchport mode trunk
  media-type rj45
!
interface GigabitEthernet0/3
  port-type nni
  channel-group 1 mode active
!
interface GigabitEthernet0/4
  port-type nni
  channel-group 1 mode active
!
tw3-main# show lacp neighbor
Flags:  S - Device is requesting Slow LACPDUs
        F - Device is requesting Fast LACPDUs
        A - Device is in Active mode       P - Device is in Passive mode

Channel group 1 neighbors

Partner's information:

<table>
<thead>
<tr>
<th>Port</th>
<th>Flags</th>
<th>Priority</th>
<th>Dev ID</th>
<th>Age</th>
<th>key</th>
<th>Key</th>
<th>Number</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gi0/3</td>
<td>SA</td>
<td>32768</td>
<td>108c.cf8d.8700</td>
<td>10s</td>
<td>0x0</td>
<td>0x1</td>
<td>0x104</td>
<td>0x3D</td>
</tr>
<tr>
<td>Gi0/4</td>
<td>SA</td>
<td>32768</td>
<td>108c.cf8d.8700</td>
<td>7s</td>
<td>0x0</td>
<td>0x1</td>
<td>0x105</td>
<td>0x3D</td>
</tr>
</tbody>
</table>

tw3-main# show spanning-tree

VLAN0001
  Spanning tree enabled protocol rstp
  Root ID  Priority 32769
  Address  108c.cf8d.7800
  This bridge is the root
  Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID  Priority 32769 (priority 32768 sys-id-ext 1)
             Address 108c.cf8d.7800
             Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
             Aging Time 300 sec

  Interface Role Sts Cost Prio.Nbr Type
  ------------------- ----- ---- ------- ----------
                Pol Desg FWD 3 128.56 P2p

VLAN0200
  Spanning tree enabled protocol rstp
  Root ID  Priority 32968
  Address  108c.cf8d.7800
  This bridge is the root
  Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

  Bridge ID  Priority 32968 (priority 32768 sys-id-ext 200)
             Address 108c.cf8d.7800
             Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
             Aging Time 300 sec
```

Link aggregation/bonding and load balancing with SAF products
Link aggregation/bonding and load balancing with SAF products

Configuration of radios is the same in all units:

<table>
<thead>
<tr>
<th>Interface</th>
<th>Role</th>
<th>Sts</th>
<th>Cost</th>
<th>Prio.Nbr</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gi0/1</td>
<td>Desg</td>
<td>FWD</td>
<td>4</td>
<td>128.1</td>
<td>P2p</td>
</tr>
<tr>
<td>Gi0/2</td>
<td>Desg</td>
<td>FWD</td>
<td>4</td>
<td>128.2</td>
<td>P2p</td>
</tr>
</tbody>
</table>

LAN1 – management port as trunk for management VLAN200.
LAN2 – LACP port as access for LACP BPDUs with traffic.

Note: D – VLAN disabled, T – port is in trunk mode (tagged), U – port is in access mode (untagged).

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