# LANCOM Tech Paper

## Design guide for hierarchical switch networks with redundancy

**With the ongoing growth of digitalization in every area of our lives and work, an ever increasing number and variety of client devices are being networked. To ensure the seamless and reliable exchange of data, these clients need networks that are intelligent and secure. Efficient logistics are essential for moving the data from where it is created to where it is consumed. This may be at the same company location or at a remote branch, depending on where the data packets have to be further processed. When it comes to the switch network, reliability is an essential aspect of planning and should be carefully considered before any hardware is purchased. After all, errors in the misconfiguration of key network components such as switches usually lead to failures of parts of or even the entire network. As a result, production downtimes and failures of the entire communication infrastructure can result in immense follow-up costs.**

**With good planning, the redundant connection of the switches across the entire network minimizes those risks of failure and increases the availability of networks. For example, link aggregation groups (LAG) allow access switches to be connected to two different switches in the aggregation layer, which yields extremely high availability (HA) and practically uninterrupted network operations. Loop-prevention mechanisms are extremely important here, in that they avoid having to use the rather inefficient spanning tree protocol and replace it with a better solution, namely redundancy through stacking.**

**This design guide uses example networks to show how a well-planned redundant network could look. It addresses IT decision-makers and network technicians with sound prior knowledge, and it can be understood as a recommendation for practical use. For a detailed explanation of the technical terms used in this tech paper, please refer to the tech paper LANCOM Fail-safe Stacking.**

### THIS TECH PAPER IN BRIEF

- Example scenarios for smaller, distributed networks with the LANCOM XS-5110F
- Example scenarios for medium-sized, distributed networks with the LANCOM XS-5116QF
- Example scenarios for high performance requirements in large distributed networks with the LANCOM XS-6128QF
- Implementation guide:
  - Stacking using link aggregation groups
  - Mixed stacks between the LANCOM XS-51xx and GS-45xx series
  - Spanning-tree and loop-protection protocols
  - Redundant connection of end devices – recommended use of LACP only

The application scenarios and network topologies for small, medium, and large local networks shown below are example designs and can easily be adapted to the actual customer scenarios. These examples are based on the managed 10G fiber-aggregation switches LANCOM XS-5110F, LANCOM XS-5116QF, and LANCOM XS-6128QF in combination with access switches from LANCOM. These options cannot be considered to be exhaustive. Also, every customer and every scenario brings its own challenges, depending on the environment and business model, as well as the actual on-site conditions.

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In order to set up a switch stack according to many of the scenarios outlined below, note that the device must be configured locally via the CLI or web GUI. Once the stack has been set up in this way, the LANCOM Management Cloud is particularly recommended for the clearly structured management of the switch network, along with the web configuration of the devices.

## LANCOM XS-5110F for smaller, distributed networks

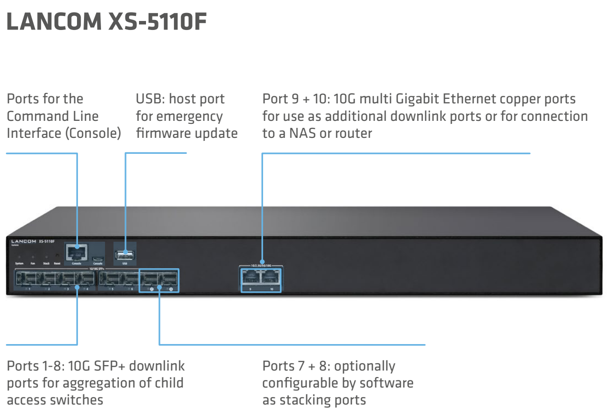


Fig. 1: Port configuration of the LANCOM XS-5110F

The LANCOM XS-5110F is the LANCOM entry-level model of aggregation switches for small-scale scenarios. With eight available 10G SFP+ downlink ports, up to eight access switches can be connected directly. Also, two 10G copper ports (ports 9 and 10) operate either as downlinks or uplinks, i.e. for connection to a gateway or firewall (e.g. the LANCOM ISG series or the LANCOM UF series) and / or a server or data storage (NAS – network attached storage / SAN – storage area network).

## Recommended stack structure and the resulting maximum network size with the LANCOM XS-5110F

As pointed out in the tech paper [LANCOM Fail-safe Stacking](), LANCOM recommends the ring topology for stacking. In the case of the LANCOM XS-5110F, two SFP+ ports are required for stacking, which leaves only six SFP+ ports for other connections (see figure 2).

Consequently, a stack featuring a maximum of eight LANCOM XS-5110F models provides up to 48 SFP+ ports (see figures 2 and 4).

Since high-density environments require the access switches to be connected redundantly, up to 24 access switches can be used for networking further end devices. The following calculation illustrates this in detail.

| Calculation of a redundant scenario for a ring-topology stack (LANCOM XS-5110F) | |
|---|---|
| **n * m/2 = possible number of access switches** | |
| **n** | Number of aggregation switches (min. 2 – max. 8) |
| **m** | Downlink ports (max. 6) |
| **/2** | Redundant connection of one access switch to two aggregation switches |
| **8 * 6/2 = 24 (max.)** | |

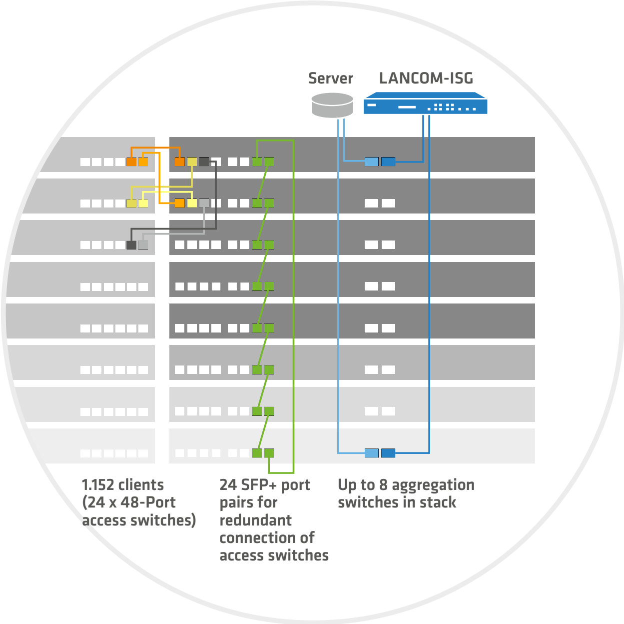


Fig. 2: Detailed view of up to eight LANCOM XS-5110F in ring-topology stacking

## XS-5110F STACKING SCENARIO GENERAL

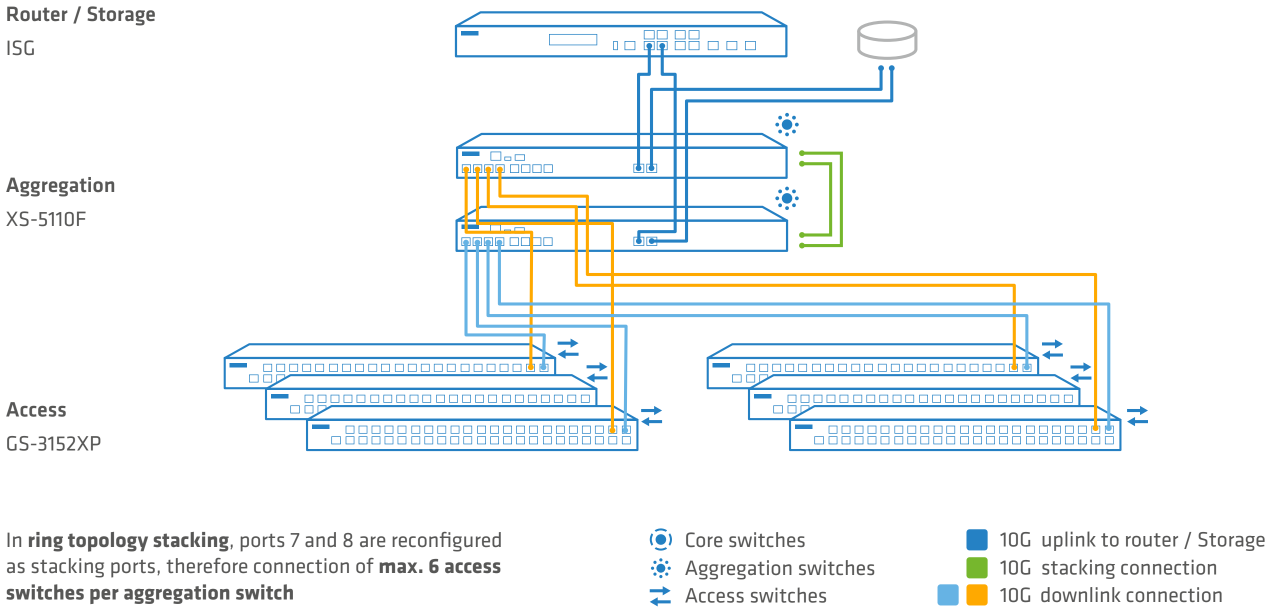


Fig. 3: General scenario with ring topology, even with only two stacked switches

## XS-5110F TWO-TIER SMALL AND MEDIUM ENTERPRISE-SZENARIO (UP TO 8 SWITCHES IN THE STACK)

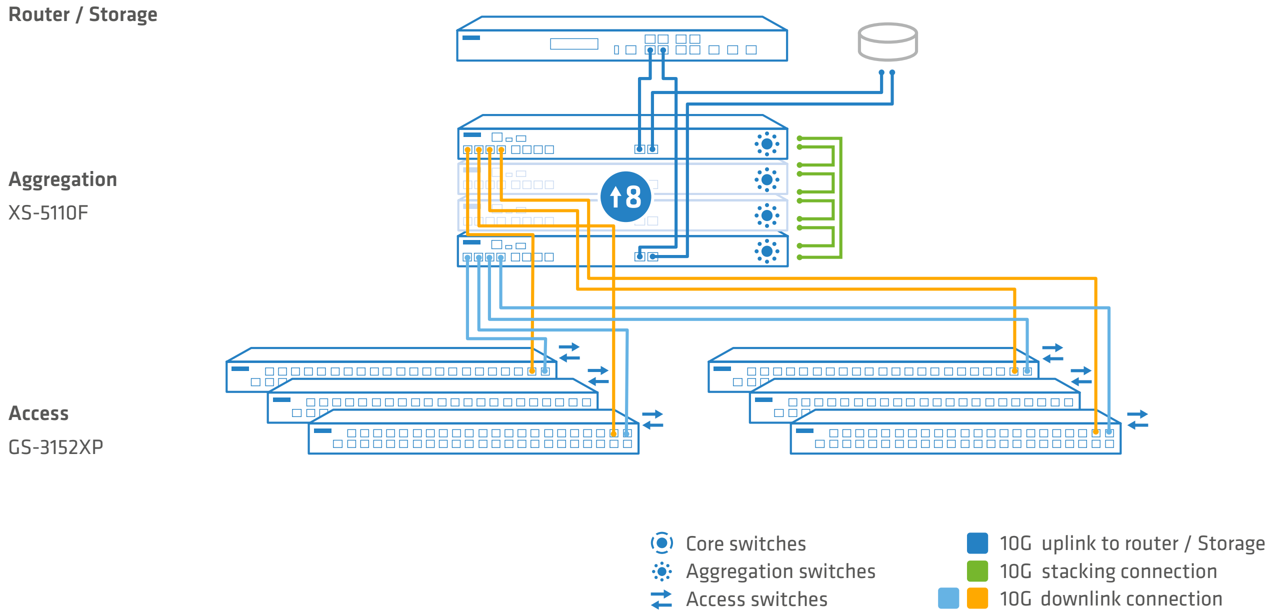


Fig. 4: Up to eight LANCOM XS-5110F in the stack to increase redundancy

## LANCOM XS-5116QF for medium-sized, distributed networks

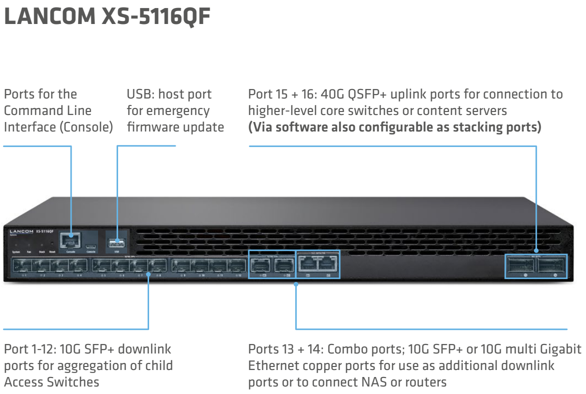


Fig. 5: Port configuration of the LANCOM XS-5116QF

The LANCOM XS-5116QF is the ideal solution for supporting the aggregation layer in medium-sized scenarios. In addition to its twelve 10G SFP+ ports for aggregating the equivalent number of lower-layer access switches, this model has two further combo ports that can either act as additional downlink ports to increase the number of aggregated access switches to up to 14, or for uplinking in the direction of the WAN or connected storage. The two 40G QSFP+ ports 15 and 16 can either be used for a very broadband uplink to the core or a server aggregation layer. They can also be reconfigured in software to be stacking ports.

## Recommended stack structure and the resulting maximum network size with the LANCOM 5116QF

Compared directly with the smaller LANCOM XS-5110F model, the LANCOM XS-5116QF is equipped with QSFP+ ports for the stacking function. Consequently, the number of SFP+ ports classified as downlink ports remains the same even when operating the switch in a stack. If we now assume that the two 10G combo ports on two stack units

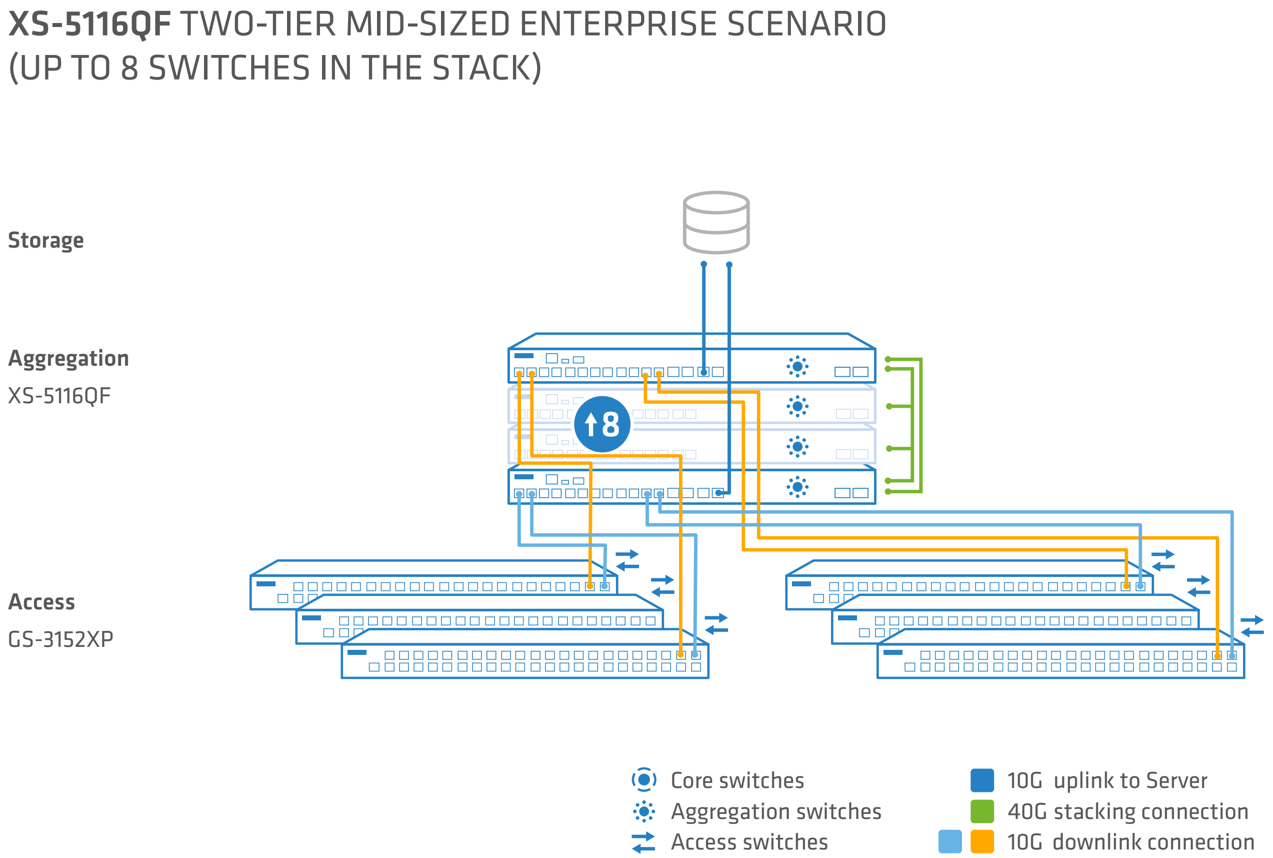


Fig. 6: Scenario for increased redundancy with up to eight LANCOM XS-5116QF in the stack

have sufficient capacity for connecting to an upper-layer router, more than twice as many SFP+ ports remain for connecting access switches than the LANCOM XS -5110F.

In the interests of redundancy, we again divide the resulting 14 ports by 2, which yields seven potential access switches per stack unit. With the maximum of eight devices per stack (see figures 6 and 7), a potential of 52 access switches can be served.

| Calculation of a redundant scenario for a ring-topology stack (LANCOM XS-5116QF) | |
|---|---|
| **n * m/2 – 2 * 2 = possible number of access switches** | |
| **n** | Number of aggregation switches (min. 2 – max. 8) |
| **m** | Downlink ports (14 x SFP+) |
| **/2** | Redundant connection of one access switch to two aggregation switches |
| **2*2** | 10G ports (for connecting storage and router) |
| **8 * 14/2 - 4 = 52 (max.)** | |

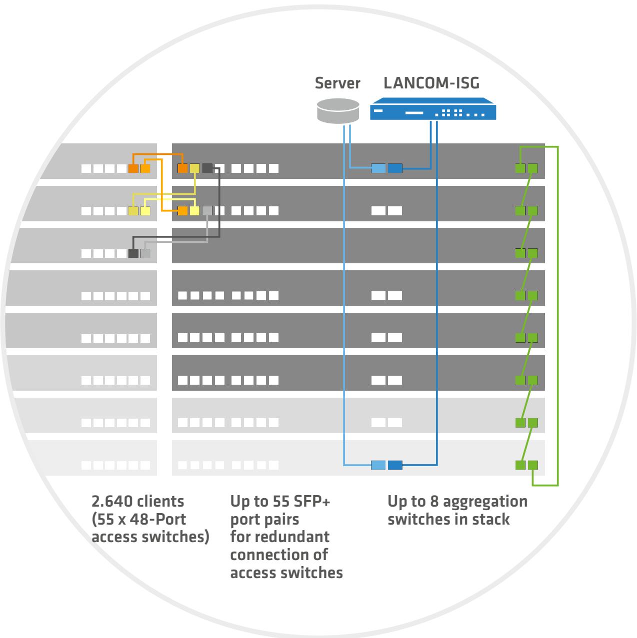


Fig. 7: Detailed view of up to eight LANCOM XS-5116QF in ring-topology stacking

## LANCOM XS-6128QF – for large, distributed networks

The LANCOM XS-6128QF is designed to offer a very low TCO; all of the ports are native, which saves on the costly modular structure commonly used by comparable competitor models. Ex-factory, this model supports the full range of port options from combo downlink (copper/fiber) and combo uplink (25G/40G) ports and thus meets high performance requirements. All ports are industry standard, including for stacking, so no expensive proprietary cables are required. Although the SFP ports are free of a vendor lock, LANCOM recommends using its own transceiver and DAC product portfolio that have been tested and optimized especially for these switches. Only in this way can a secure operation be guaranteed. The LANCOM XS-6128QF has 24 SFP+ ports, four SFP28 25G ports, two QSFP+ 40G ports, and four dedicated rear-panel SFP DD 50G stacking ports that also accommodate 25G optical transceivers. For example, the option of using SFP+ modules in the 4x 25G SFP28 ports allows for up to 4 additional SFP+ ports. This model also supports decentralized stacking with standard 25G short- and long-range modules. As a result, the LANCOM XS-6128QF is the high-performance hardware basis for very demanding networks.

**LANCOM XS-6128QF**

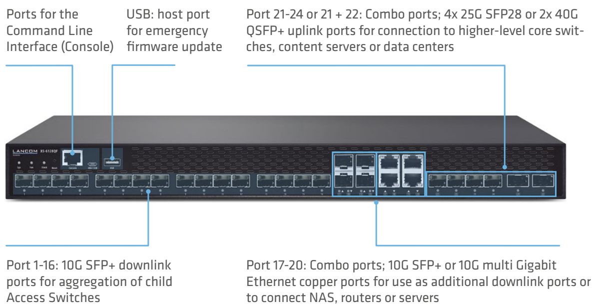


Fig. 8: Port configuration of the LANCOM XS-6128QF

**LANCOM XS-6128QF**

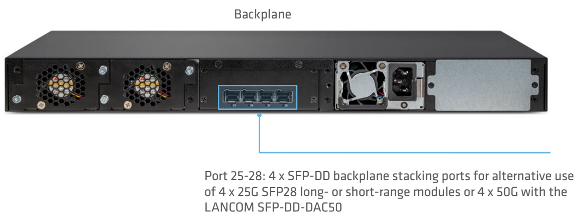


Fig. 9: Stacking ports on the back panel of the LANCOM XS-6128QF (4 x 50G)

## Recommended stack structure and the resulting maximum network size with the LANCOM XS-6128QF

Characterizing the LANCOM XS-6128QF are its high-throughput uplink ports and four dedicated 50G stacking ports. Consequently, even in a stacked state the device supports a high-bandwidth uplink to an upper-layer core, as well as a 100G connection to a data center or storage. This aggregation switch meets the highest requirements and port capacities demanded by enterprise networks.

With regard to the port configuration, the 20 available downlink ports allow up to ten access switches to operate redundantly at each aggregation switch. Theoretically, a stack of eight could connect up to 80 access switches (see figures 10 and 11).

| Calculation of a redundant scenario for a ring-topology stack (LANCOM XS-6128QF) | |
|---|---|
| **n * m/2 = possible number of access switches** | |
| **n** | Number of aggregation switches (max. 8) |
| **m** | Downlink ports (max. 20) |
| **/2** | Redundant connection of one access switch to two aggregation switches |
| **8 * 20/2 = 80 (max.)** | |

As an illustration of the performance available from the calculation outlined above, we can take the example of an imposing office tower on the Frankfurt skyline. The second highest building in the metropolis on the river Main provides office space for almost 3,000 people spread over 56 floors. The network is equipped with eight XS-6128QF models in an aggregation switch stack connected to at least one data center or core switch and also to the LANCOM GS-4554XP as access switches.  An access switch from the GS-45xx series was deliberately chosen for this enterprise-class scenario, because the Limited Lifetime Warranty that comes with it is often a requirement in this market. The GS-45xx series also offers two power supplies as well as N+1 fans for redundancy, making it the ideal basis for high-availability networks of this size.

This 8-way cluster provides a total of 160 SFP+ downlink ports, which can be connected redundantly via the addressed 80 LANCOM GS-4554XP. Each of the access switches provides a maximum of 48 client ports. What this means is: This network connects up to max. 80 access switches of the previously mentioned model, each operating 48 downlink ports, i.e. up to 3,840 clients can be connected. The uplink ports on these aggregation switches as described above are used to connect to the upper-layer core. The 4x 50G SFP-DD stacking ports on the rear panel provide 200 Gbps port capacity. This corresponds exactly to the 20x SFP+ downlink ports (non-blocking). Full-duplex operation offers a stacking capacity of 400 Gbps.

| Illustrative calculation |
|---|
| 8 * XS-6128QF * 20 downlink ports = 160 downlink ports<br>160 downlink ports / 2 (redundant operation) = 80 access switches |
| 80 possible access switches (each with 48 downlink ports)<br>= 80 access switches * 48 downlink ports = **3,840 ports** |

For the three-tier scenario (core – aggregation – access) required in the office building, the LANCOM XS-6128QF is the ideal solution for implementing a network below the aggregation layer (i.e. the distribution layer throughout the building) by implementing the system described below (see scenario in figure 10).

## XS-6128QF THREE-TIER LARGE ENTERPRISE SCENARIO (UP TO 8 SWITCHES IN THE STACK)

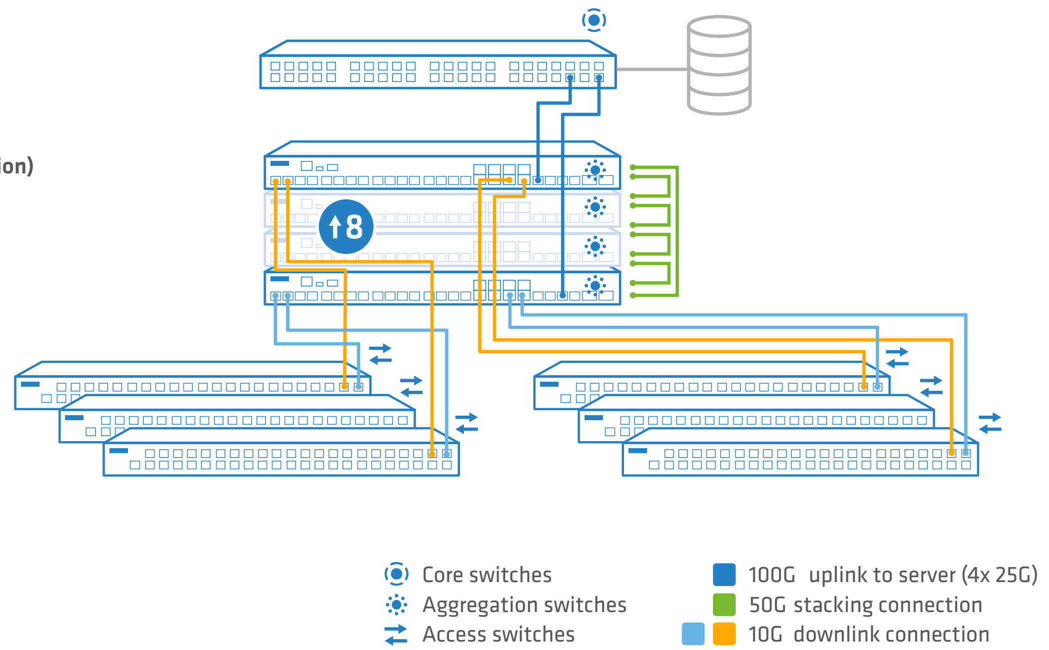


Fig. 10: Three-tier scenario for increased redundancy with up to eight LANCOM XS-6128QF in the stack


Fig. 11: Detailed view of up to eight LANCOM XS-6128QF in ring-topology stacking

Even with lesser network requirements that do not necessarily require a core switch (i.e. a three-tier design), the LANCOM XS-6128QF is still an excellent choice as a "collapsed core" in a two-tier scenario (see figure 12).

Upstream of the LANCOM XS-6128QF, using the example of the Frankfurt office building, there is only the data center or, potentially, a video content system as is often the case in schools. This scenario is generally relevant for educational institutions and is typical for them. In redundancy scenarios where each access switch is connected to the aggregation layer by two 10G ports, using the 25G ports that are not used for the uplink in the stack makes it possible to operate a network with 184x48/2, i.e. 4,416 ports. To achieve the latter, each of the free SPF28 25G ports is equipped with an SFP+ 10G transceiver. This is possible because the SFP28 optics standard is also backwards compatible with 10G.

## **XS-6128QF** TWO-TIER LARGE ENTERPRISE SCENARIO (UP TO 8 SWITCHES IN THE STACK)

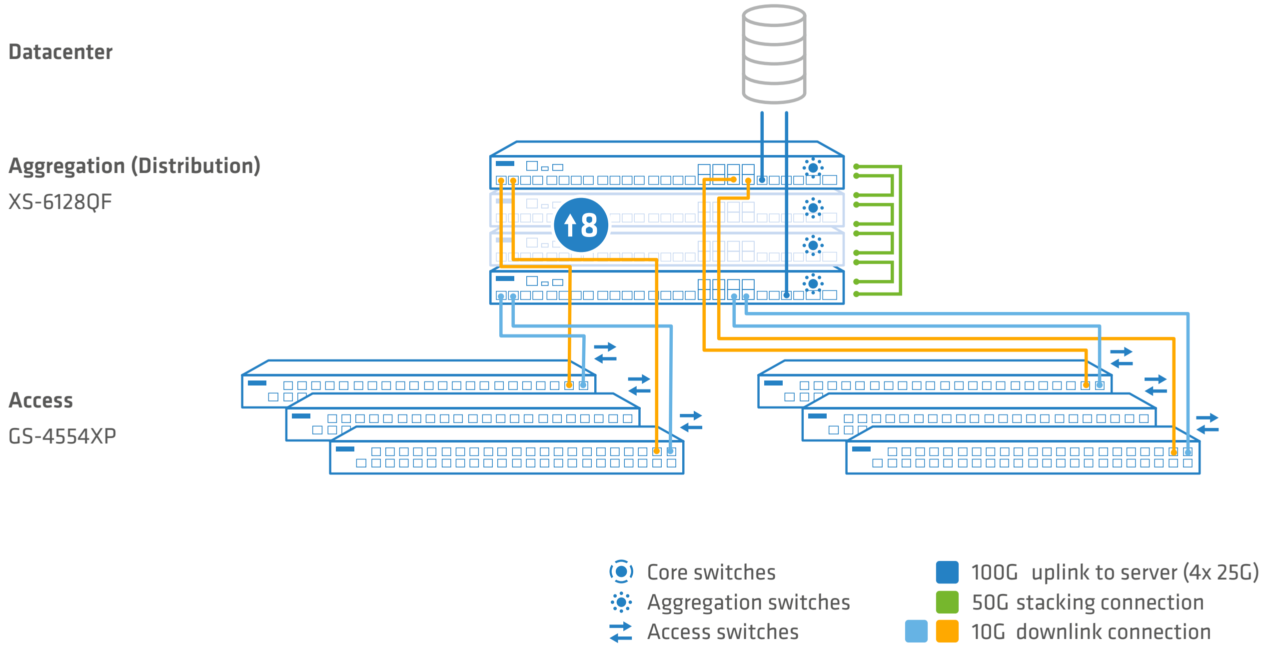


Fig. 12: Collapsed core scenario and uplink to the data center with the LANCOM XS-6128QF

### Implementation guide for the above scenarios

Now that one or more practical scenarios has been presented for each LANCOM aggregation switch, the following takes a technical look at the necessary switch protocols mentioned above in closer detail. The terms LAG and LACP play a key role and are explained below.

### A brief digression: The difference between LAG and LACP

The technology for implementing link bundling and load balancing was named LAG (Link Aggregation Group), and initially the standard did not specify a protocol. Put simply, a LAG merges a number of physical connections between network devices into a single logical connection.

LAG is also understood to be a manual or static mode thanks to the work involved, because users have to manually create a port channel and add member interfaces to it. Once interdependent group links have been set up in this way, all of the links become active and start forwarding data packets. If an active link fails, the other links in the group remain active and share the load of the data traffic between themselves. The mode is able to detect disconnected member links, but it cannot detect other errors like incorrect link connections or link-layer errors.

LACP, on the other hand, is part of the global standard IEEE 802.3ad (Link Aggregation) and is therefore a protocol for the automatic configuration and maintenance of LAGs. LACP uses LACPDUs (LACP data packets, request-response principle) as an automated negotiation mechanism between two or more network devices, so that a logically grouped link can be formed and started automatically according to its configuration. Further, LACP is also responsible for maintaining the link status and constantly exchanges information about the data packets. It therefore reacts dynamically to changes on the network without requiring reconfiguration (see figures 13 and 14).

LAG configuration has been available for XS-series switches since firmware version LCOS SX 5.20 REL, and for the other two series of switches for some time already. In the the LANCOM Management Cloud (LMC), the configuration is found under the overview of the device details. Once there, you simply use the port diagram and assign a LAG to all of the ports that should form a group (see figure 15).

## Stacking using link aggregation groups

Along with the internal stacking protocol described in detail in the tech paper LANCOM Fail-safe Stacking, LAG is the most important tool for redundancy and load balancing. As described in the scenarios above, access switches always need to be physically connected to two

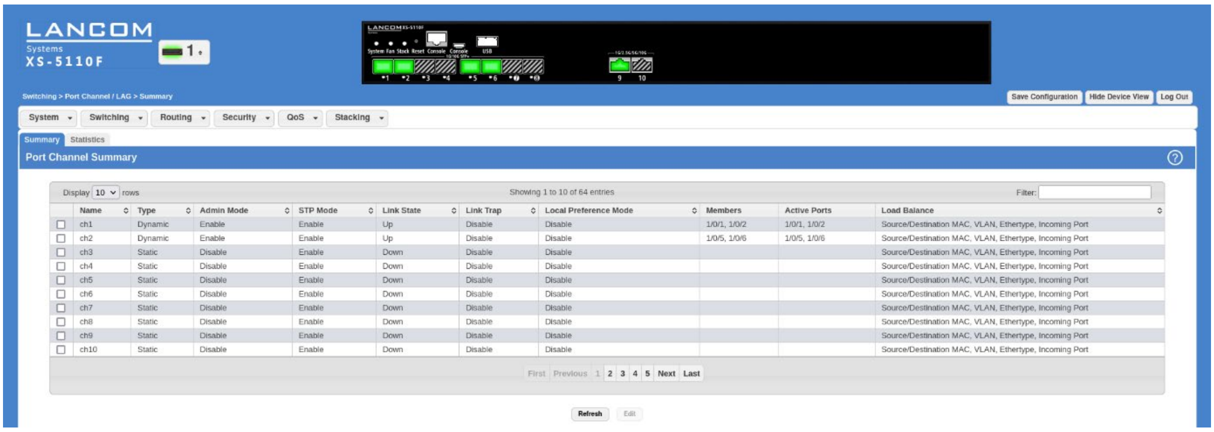


Fig. 13: LAG configuration XS series

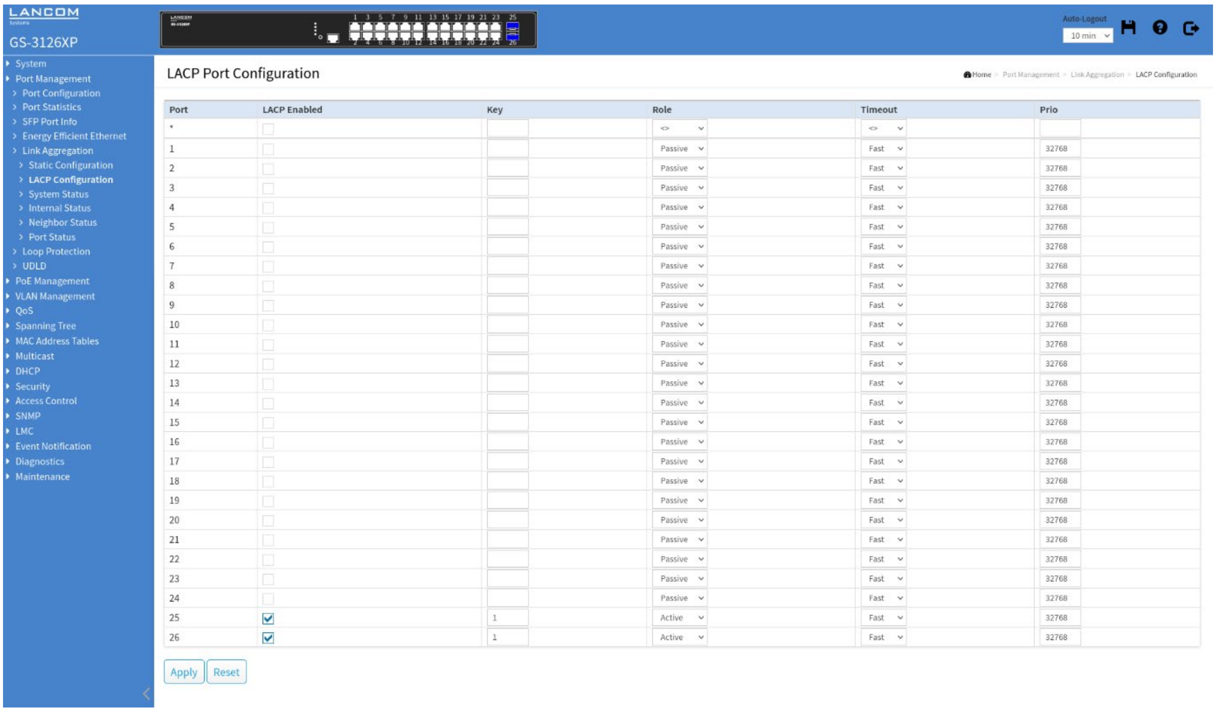


Fig. 14: Configuration, LANCOM GS-31/35 series

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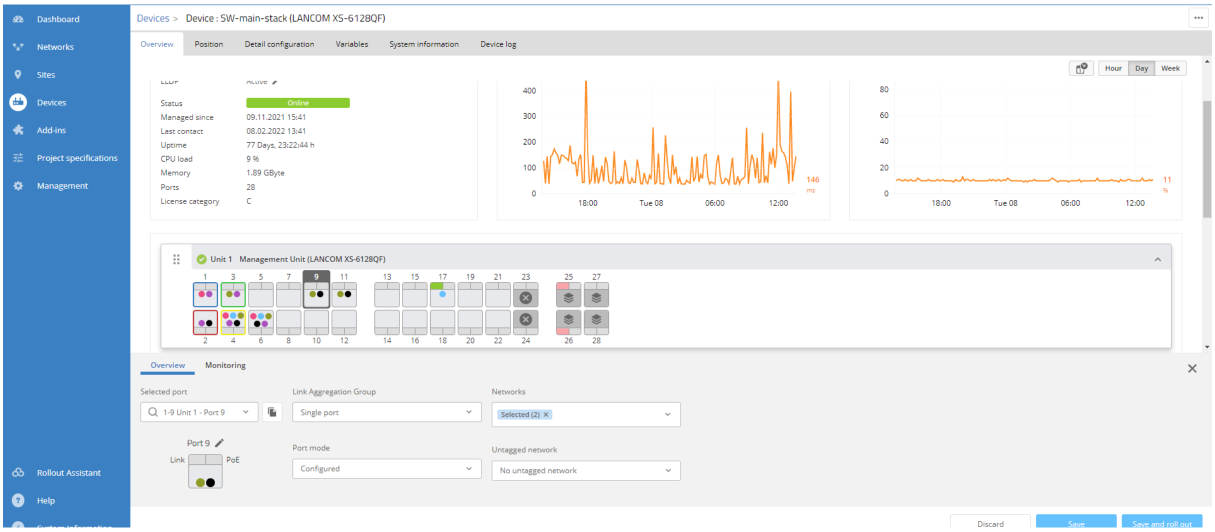


Fig. 15: LAG configuration via the LMC

different stack units on the aggregation layer. Apart from the redundancy through two independent physical connections, the LACP (IEEE 802.3ad) protocol associated with the LAG not only shares the load between the connections it is running; it also uses LACPDUs to automatically detect, without a discernible loss of data, whether a link has failed or is reconnected. The last point in particular is a major advantage over the spanning tree protocol (STP), as this uses only one of the two physical connections and only ever uses the other connection for redundancy, i.e. in the event of an error. Depending on the version used, the STP produces failures for up to 30 seconds (further information can be found in the "STP" chapter below).

For the sake of completeness, we should note that LANCOM switches support a LAG of up to eight connections, but the scenarios outlined above rarely require more than two connections. This is simply because the access and aggregation layers are designed to be connected by 10G connections only. The 2x10G = 20G as uplink from the access switch resulting from LACP is usually sufficient to avoid forming a network bottleneck, since it can be assumed that with 48 x 1G access ports, end devices rarely request the full 1G. Many of the connections are for printers, IP telephones, and other less data-intensive end devices. Lastly it should be noted that the LAGs must be configured both on the access switches and on the aggregation switches. Although the screenshots in figures 13 and 14 show the LAG configuration in the individual web GUI menus, a similar configuration can also be set up using the CLI or even as recommended with the LANCOM Management Cloud (LMC).

## Mixed stacks combining the XS and GS-45xx series

Now that we have an understanding of network redundancy via LACP, we now continue with a special LANCOM feature for networks operating at a single site but that have a port mix of fiber optic and CAT cables. A mixed stack combining switches from the XS-51xx and GS-45xx series offers an ideal basis for this. But before we get into the details, we need to move away from the network-layer related terms "aggregation switch" and "access switch". For a better understanding, the XS-51xx switches are now viewed simply as fiber switches (since the majority of the ports are SFP+ ports), and correspondingly the GS-45xx is seen as a copper switch with the option of powering end devices by PoE. In this case the switches are technical equivalents and there is no reason to consider the XS series to be superior. These mixed stacks are feasible because

```
User:admin
Password:********
(GS-4530XP)>en

(GS-4530XP)#show switch

    Management   Standby    Preconfig         Plugged-in        Switch        Code
SW    Switch     Status     Model ID          Model ID          Status        Version
--- ----------- --------- ---------------- ---------------- ------------- -----------
1   Stack Mbr   Oper Stby GS-4530XP        GS-4530XP        OK            5.20.0054DBG
2   Mgmt Sw               XS-5116QF        XS-5116QF        OK            5.20.0054DBG
3   Stack Mbr             XS-5116QF        XS-5116QF        OK            5.20.0054DBG
4   Stack Mbr             GS-4530XP        GS-4530XP        OK            5.20.0054DBG
5   Stack Mbr             GS-4530XP        GS-4530XP        OK            5.20.0054DBG
6   Stack Mbr             GS-4530XP        GS-4530XP        OK            5.20.0054DBG
7   Stack Mbr             GS-4554XP        GS-4554XP        OK            5.20.0054DBG
8   Stack Mbr             GS-4554XP        GS-4554XP        OK            5.20.0054DBG

(GS-4530XP)#
```

Fig. 16: Mixed stack in the CLI

switches of the GS-45xx and XS-51xx series share the same switch MAC family and, as a result, they share the same firmware version. Important for creating the stack is the selection and configuration of the correct stacking interfaces. LANCOM GS-45xx models can only be stacked with the LANCOM XS-5110F by using the two SFP+ ports, and the LANCOM XS-5116QF can only be stacked by using the two QSFP+ ports. See also figure 17.

| | XS-5110F | XS-5116QF | XS-6128QF | GS-45xx series |
|---|---|---|---|---|
| XS-5110F | ✓ via SFP+ ports | – | – | ✓ via SFP+ ports |
| XS-5116QF | – | ✓ via QSFP+ ports | – | ✓ via QSFP+ ports |
| XS-6128QF | – | – | ✓ via SFP-DD-Ports | – |
| GS-45xx series | ✓ via SFP+ ports | ✓ via QSFP+ ports | – | ✓ via QSFP+ or SFP+ ports |

Fig. 17: Stacking matrix

Figure 16 shows an example of how a mixed stack could look in the CLI.

## Spanning tree protocol (STP) and loop protection protocol

As previously explained for the scenarios, LANCOM recommends using LACP instead of the spanning tree protocol (STP) where connection redundancy is a requirement. However, operating the spanning tree protocol in combination with the loop protection protocol offers significant advantages for very large, partially decentralized scenarios and for scenarios with large numbers of access switches. Also, restrictions due to the building's construction that limit the number of possible connections make the STP a good alternative. This minimizes the risk of loop formation, particularly in client access mode. We will not discuss the technical differentiation between the spanning tree standards MSTP (Multi-STP, IEEE 802.1s) and RSTP (Rapid-STP, IEEE 802.1w) here. Instead we make reference to the relevant literature. LANCOM recommends MSTP as this is the newest and most capable variant of STP. In the following, we present two typical examples to illustrate the purpose of MSTP.

### Scenario 1: MSTP at remote sites, university campus

If we project the above scenario onto a university campus, then the two stacks can be understood to be two independent data centers somewhere in the city (see figure 18). They may be separated by several kilometers, in which case they could be connected by single-mode fiber-optic links. The two data centers are connected to the university backbone, which also hosts the gateway to the WAN. If the connection from the left-hand stack to the WAN gateway

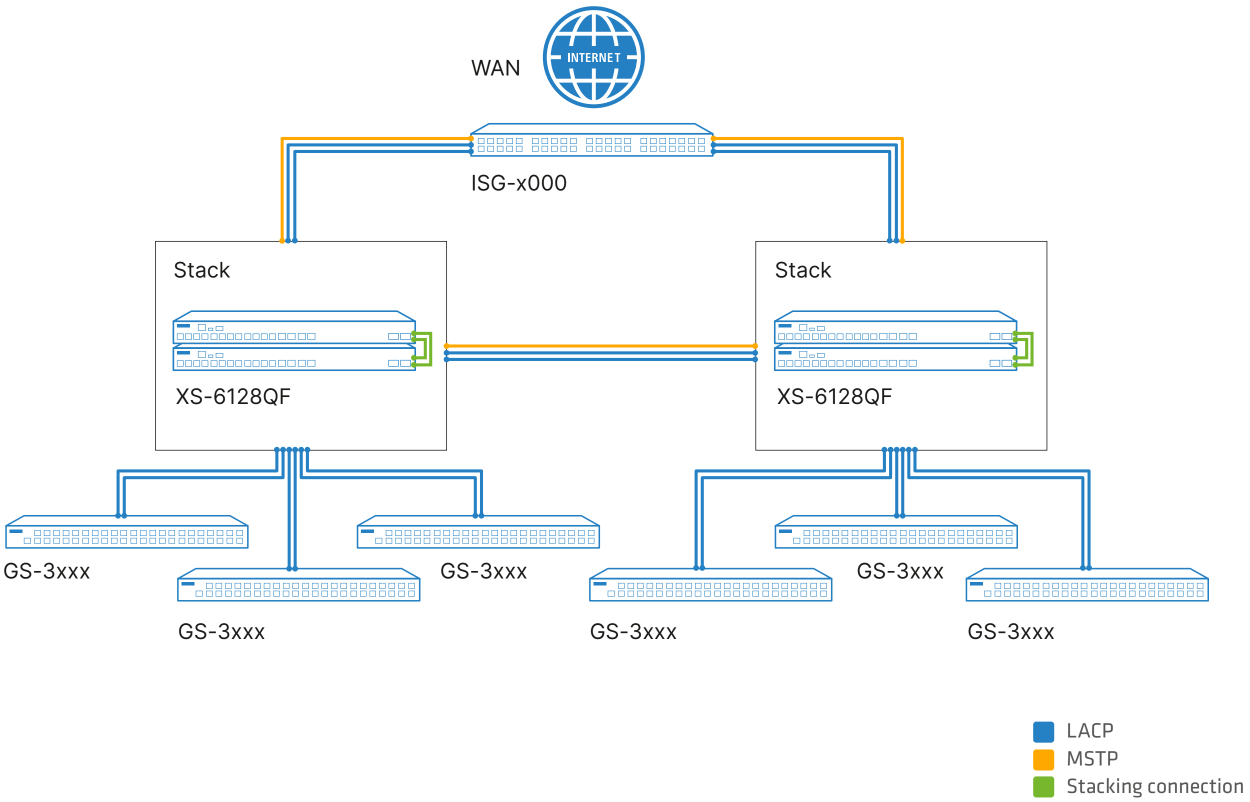


Fig. 18: MSTP at decentral sites

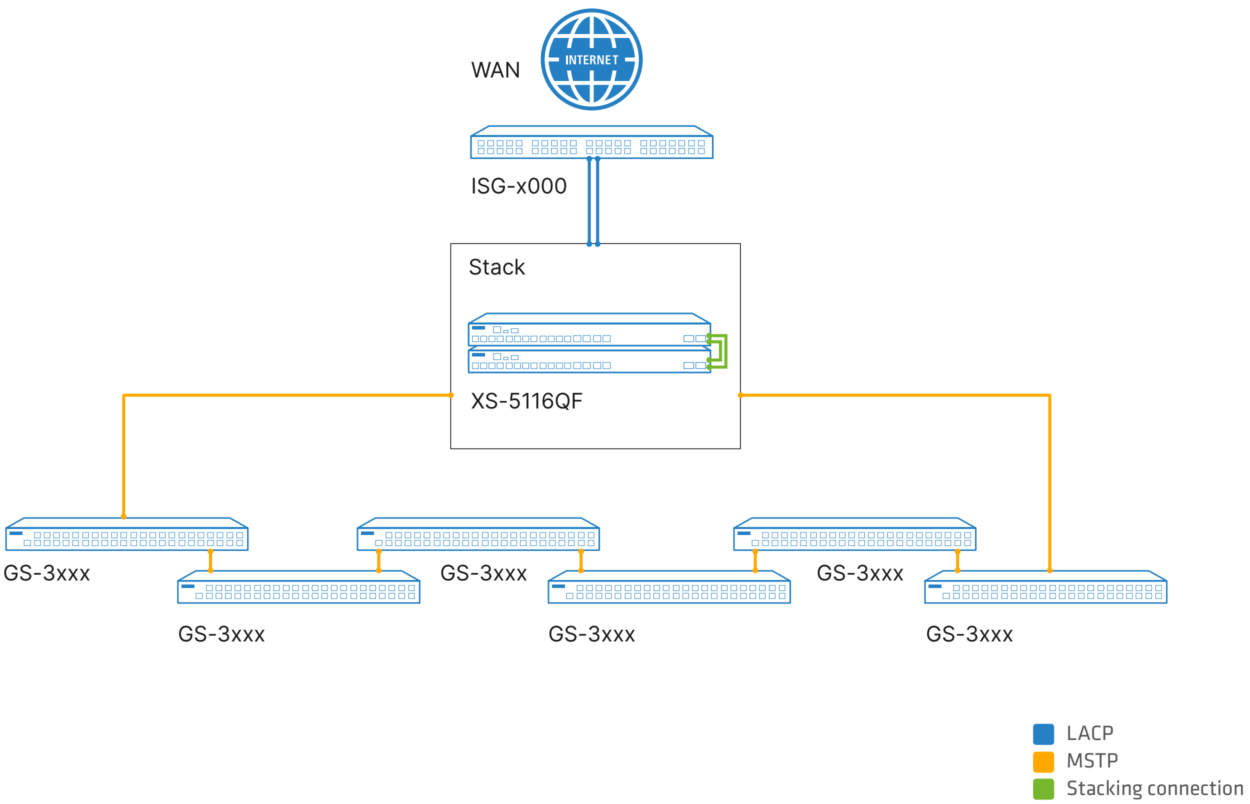


Fig. 19: MSTP with numerous cascaded access switches

is interrupted—for example, due to road works or other unforeseeable events—the stack can still route to the WAN via the right-hand stack without the site being cut off completely. This type of redundancy is implemented by the spanning tree. As long as there is no error, the middle connection between the stacks stays inactive. On the access layer, the recommendation to use LACP instead of MSTP applies for this scenario.

For the sake of completeness we will include an example of MSTP on the access layer in the following example:

### Scenario 2: MSTP on the access layer, with many access switches

Where large numbers of access ports have to be implemented on a tight budget, the first thing to be sacrificed will generally be the stack of aggregation switches, since the large number of access switches is unavoidable. To retain a certain amount of redundancy despite all this, a ring is constructed and this requires the operation of MSTP. It is also possible to set up double connections via LACP here. Important in the scenario in figure 19 is that, in addition to MSTP, the loop protection protocol must be enabled for all ports on the access switches, i.e. globally. Otherwise, the risk is too great that someone will unknowingly plug-in a loop on an access switch or across multiple switches. With the aggregation switches, the risk of this is comparatively small and loop protection is only required on the ports that are connected to the access layer. Figure 18 illustrates this scenario with MSTP for many access switches.

## Redundant connection of end devices on the access layer

Now that we have covered the various redundancy concepts within the switch network, the final option is to connect end devices redundantly. Here too, LANCOM recommends the use of LACP. Alternative solutions such as NIC Teaming from Microsoft in practice require considerably more effort for configuration, and the lack of uniform standards mean that these NIC Teaming solutions also suffer from problems from MAC flapping and packet loss.

## Summary

Even if these scenarios cannot reflect every possible network design, these examples give a good overview of what can be achieved with LANCOM switches. In particular, the option to construct mixed stacks of fiber and copper switches with and without PoE is an outstanding feature of the LANCOM portfolio. The multi-functional configuration options via the web GUI, CLI, and the LANCOM Management Cloud are a further highlight for LANCOM switches. We also refer to the other switch-related tech papers, which provide even deeper insights into the configurations:

- Tech paper on Hierarchical switch infrastructures
- Tech paper on LANCOM XS-6128QF configuration options
- Tech paper LANCOM Fail-safe stacking with the XS series





LANCOM Systems GmbH I Adenauerstr. 20/B2 I 52146 Wuerselen I Germany I E-mail info@lancom.de