ADVANCING GLOBAL COMMUNICATIONS

ANSI/TIA-942-B-2017
APPROVED: JULY 12, 2017

TIA STANDARD

Telecommunications Infrastructure Standard for Data Centers

TIA-942-B
(Revision of TIA-942-A)

July 2017

TELECOMMUNICATIONS INDUSTRY ASSOCIATION
tiaonline.org

NOTICE

TIA Engineering Standards and Publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for their particular need. The existence of such Standards and Publications shall not in any respect preclude any member or non-member of TIA from manufacturing or selling products not conforming to such Standards and Publications. Neither shall the existence of such Standards and Publications preclude their voluntary use by Non-TIA members, either domestically or internationally.

Standards and Publications are adopted by TIA in accordance with the American National Standards Institute (ANSI) patent policy. By such action, TIA does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the Standard or Publication.

This Standard does not purport to address all safety problems associated with its use or all applicable regulatory requirements. It is the responsibility of the user of this Standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before its use.

Any use of trademarks in this document are for information purposes and do not constitute an endorsement by TIA or this committee of the products or services of the company.

(From Standards Proposal No. ANSI/TIA-PN-942-B-D1, formulated under the cognizance of the TIA TR-42 Telecommunications Cabling Systems, TR-42.1 Subcommittee on Commercial Building Telecommunications Cabling).

Published by
©TELECOMMUNICATIONS INDUSTRY ASSOCIATION
Technology and Standards Department
1320 N. Courthouse Road, Suite 200
Arlington, VA 22201 U.S.A.

**PRICE: Please refer to current Catalog of
TIA TELECOMMUNICATIONS INDUSTRY ASSOCIATION STANDARDS
AND ENGINEERING PUBLICATIONS
or call IHS, USA and Canada
(1-877-413-5187) International (303-397-2896)
or search online at http://www.tiaonline.org/standards/catalog/**

NOTICE OF DISCLAIMER AND LIMITATION OF LIABILITY

The document to which this Notice is affixed (the "Document") has been prepared by one or more Engineering Committees or Formulating Groups of the Telecommunications Industry Association ("TIA"). TIA is not the author of the Document contents, but publishes and claims copyright to the Document pursuant to licenses and permission granted by the authors of the contents.

TIA Engineering Committees and Formulating Groups are expected to conduct their affairs in accordance with the TIA Procedures for American National Standards and TIA Engineering Committee Operating Procedures, the current and predecessor versions of which are available at http://www.tiaonline.org/standards/ec-procedures)/TIA's function is to administer the process, but not the content, of document preparation in accordance with the Manual and, when appropriate, the policies and procedures of the American National Standards Institute ("ANSI"). TIA does not evaluate, test, verify or investigate the information, accuracy, soundness, or credibility of the contents of the Document. In publishing the Document, TIA disclaims any undertaking to perform any duty owed to or for anyone.

If the Document is identified or marked as a project number (PN) document, or as a standards proposal (SP) document, persons or parties reading or in any way interested in the Document are cautioned that: (a) the Document is a proposal; (b) there is no assurance that the Document will be approved by any Committee of TIA or any other body in its present or any other form; (c) the Document may be amended, modified or changed in the standards development or any editing process.

The use or practice of contents of this Document may involve the use of intellectual property rights ("IPR"), including pending or issued patents, or copyrights, owned by one or more parties. TIA makes no search or investigation for IPR. When IPR consisting of patents and published pending patent applications are claimed and called to TIA's attention, a statement from the holder thereof is requested, all in accordance with the Manual. TIA takes no position with reference to, and disclaims any obligation to investigate or inquire into, the scope or validity of any claims of IPR. TIA will neither be a party to discussions of any licensing terms or conditions, which are instead left to the parties involved, nor will TIA opine or judge whether proposed licensing terms or conditions are reasonable or non-discriminatory. TIA does not warrant or represent that procedures or practices suggested or provided in the Manual have been complied with as respects the Document or its contents.

If the Document contains one or more Normative References to a document published by another organization ("other SSO") engaged in the formulation, development or publication of standards (whether designated as a standard, specification, recommendation or otherwise), whether such reference consists of mandatory, alternate or optional elements (as defined in the TIA Procedures for American National Standards) then (i) TIA disclaims any duty or obligation to search or investigate the records of any other SSO for IPR or letters of assurance relating to any such Normati e Reference; (ii) TIA's policy of encouragement of voluntary disclosure (see TIA Procedures for American Nation l Standards Annex C.1.2.3) of Essential Patent(s) and published pending patent applications shall apply; and (i) Information as to claims of IPR in the records or publications of the other SSO shall not constitute identification to TIA of a claim of Essential Patent(s) or published pending patent applications.

TIA does not enforce or monitor compliance with the contents of the Document. TIA does not certify, inspect, test r otherwise investigate products, designs or services or any claims of compliance with the contents of the Document.

ALL WARRANTIES, EXPRESS OR IMPLIED, ARE DISCLAIMED, INCLUDING WITHOUT LIMITATION, ANY AND ALL WARRANTIES CONCERNING THE ACCURACY OF THE CONTENTS, ITS FITNESS OR APPROPRIATENESS FOR A PARTICULAR PURPOSE OR USE, ITS MERCHANTABILITY AND ITS NONINFRINGEMENT OF ANY THIRD PARTY'S INTELLECTUAL PROPERTY RIGHTS. TIA EXPRESSLY DISCLAIMS ANY AND ALL RESPONSIBILITIES FOR THE ACCURACY OF THE CONTENTS AND MAKES NO REPRESENTATIONS OR WARRANTIES REGARDING THE CONTENT'S COMPLIANCE WITH ANY APPLICABLE STATUTE, RULE OR REGULATION, OR THE SAFETY OR HEALTH EFFECTS OF THE CONTENTS OR ANY PRODUCT OR SERVICE REFERRED TO IN THE DOCUMENT OR PRODUCED OR RENDERED TO COMPLY WITH THE CONTENTS.

TIA SHALL NOT BE LIABLE FOR ANY AND ALL DAMAGES, DIRECT OR INDIRECT, ARISING FROM OR RELATING TO ANY USE OF THE CONTENTS CONTAINED HEREIN, INCLUDING WITHOUT LIMITATION ANY AND ALL INDIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES (INCLUDING DAMAGES FOR LOSS OF BUSINESS, LOSS OF PROFITS, LITIGATION, OR THE LIKE), WHETHER BASED UPON BREACH OF CONTRACT, BREACH OF WARRANTY, TORT (INCLUDING NEGLIGENCE), PRODUCT LIABILITY OR OTHERWISE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THE FOREGOING NEGATION OF DAMAGES IS A FUNDAMENTAL ELEMENT OF THE USE OF THE CONTENTS HEREOF, AND THESE CONTENTS WOULD NOT BE PUBLISHED BY TIA WITHOUT SUCH LIMITATIONS.

Telecommunications Infrastructure Standard for Data Centers

Table of Contents

List of figures

List of tables

FOREWORD

(This foreword is not considered part of this Standard.)

This Standard was developed by TIA Subcommittee TR-42.1.

Approval of this Standard

This Standard was approved by the Telecommunications Industry Association (TIA) Subcommittee TR 42.1, TIA Technical Engineering Committee TR 42, and the American National Standards Institute (ANSI).

ANSI/TIA reviews standards every 5 years. At that time, standards are reaffirmed, revised, or withdrawn according to the submitted updates. Updates to be included in the next revision of this Standard should be sent to the committee chair or to TIA.

Contributing organizations

More than 60 organizations within the telecommunications industry (including manufacturers, consultants, end users, and other organizations) contributed their expertise to the development of this Standard.

Documents superseded

This Standard replaces ANSI/TIA-942-A dated August 2012 and its addenda.

This Standard incorporates the technical content of ANSI/TIA-942-A, Addendum 1, *Cabling Guidelines for Data Center Fabrics*

Major modifications from ANSI/TIA-942-A

The major modifications in ANSI/TIA-942-B from ANSI/TIA-942-A include:

- Added MPO-16 and MPO-32 (ANSI/TIA-604-18) and MPO-24 (ANSI/TIA-604-5) as options for termination of more than two fibers in addition to the MPO-12 connector
- Added category 8 as an allowed type of balanced twisted-pair cable. Changed recommendation for category 6A balanced twisted-pair cable to category 6A or higher.
- Added OM5 as an allowed and recommended type of multimode fiber cable.
- Added 75-ohm broadband coaxial cables and connectors as specified in ANSI/TIA-568.4-D as allowed types of coaxial cables and connectors.
- Added recommendation to not install optical fiber cords and cables (both bend insensitive and non-bend insensitive) without adequate armoring or sufficiently thick jacket in pathways that can create microbends, such as non-continuous cable supports, wire basket trays, and cable ladders without radiused cable supports or solid bottoms.
- Reduced quantity of convenience outlets required on computer room walls.
- Local fire protection codes may be used instead of NFPA 75.
- Power for air conditioning systems and controls in computer rooms and entrance rooms should be redundant, but do not need to be powered from the same PDUs or panel boards that serve ICT equipment in the room.
- Recommended maximum cable lengths for direct attach cabling in EDAs has been reduced from 10 m (33 ft) to 7 m (23 ft). Additional guidance added that direct attach cabling between rows is not recommended.
- Added recommendation that cabinets be at 1200 mm (48”) deep and to consider cabinets wider than 600 mm (24”) wide.

- Added recommendation to consider preterminated cabling to reduce installation time and improve consistency and quality of terminations.
- Added recommendation to consider needs for proper labeling, cable routing, cable management, and ability to insert and remove cords without disrupting existing or adjacent connections.
- Adds normative reference to ANSI/TIA-5017 regarding physical security for the data center telecommunications infrastructure.
- Adds normative reference to ANSI/TIA-862-B regarding requirements for cabling for intelligent building systems including networked data center electrical, mechanical, and security equipment.
- Added reference to TIA TSB 162-A for guidelines regarding cabling for wireless access points in data centers
- Added reference to TIA TSB-5018 for guidelines regarding cabling for distributed antenna systems in data centers.
- Added reference to TIA TSB-184-A for guidelines regarding power delivery over balanced twisted-pair cabling.
- Numerous changes to the rating tables in Annex F including those that specify concurrent maintainability for Rating-3 (formerly Tier 3) and fault tolerance for Rating-4 (formerly Tier 4).

Relationship to other TIA standards and documents

The following are related standards regarding various aspects of structured cabling that were developed and are maintained by Engineering Committee TIA TR-42. An illustrative diagram of the ANSI/TIA-568 Series relationship to other relevant TIA standards is given in figure 1.

- ANSI/TIA-568.0-D, *Generic Telecommunications Cabling for Customer Premise*s
- ANSI/TIA-568.1-D, *Commercial Building Telecommunications Infrastructure Standard*
- ANSI/TIA-568-2.C, *Balanced Twisted-Pair Telecommunications Cabling and Components standard*
- ANSI/TIA-568.3-D, *Optical Fiber Cabling and Components Standard*
- ANSI/TIA-568.4.D, *Broadband Coaxial Cabling and Components Standard*
- ANSI/TIA-569-D, *Telecommunications Pathways and Spaces*
- ANSI/TIA-606-C, *Administration Standard for Telecommunications Infrastructure*
- ANSI/TIA-607-C, *Telecommunications Bonding and Grounding (Earthing) for Customer Premises*
- ANSI/TIA-758-B, *Customer-Owned Outside Plant Telecommunications Infrastructure Standard*
- ANSI/TIA-862-B, *Structured Cabling Infrastructure Standard for Intelligent Building Systems*
- ANSI/TIA-5017, *Telecommunications Physical Network Security Standard*

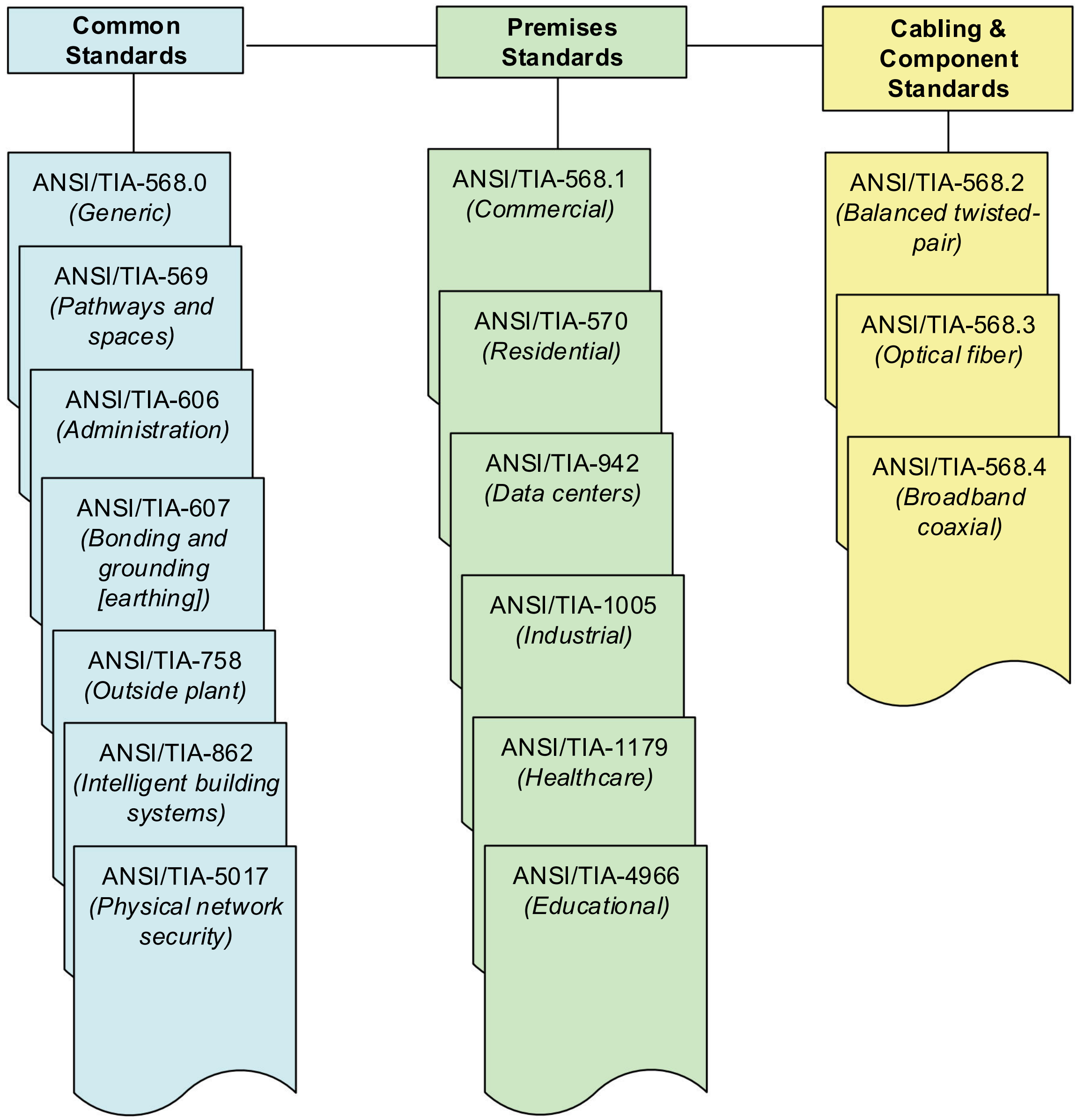


Figure 1: Illustrative relationship between the ANSI/TIA-568 Series and other relevant TIA standards

The following documents may also be useful to the reader:

- *National Electrical Safety Code*® (*NESC*®) (IEEE C 2-2012)
- *National Electrical Code*® (*NEC*®) (NFPA 70-2014)

Useful supplements to this Standard are the BICSI *Telecommunications Distribution Methods Manual*, the *Outside Plant Design Reference Manual*, and the *Information Transport Systems Installation Methods Manual*. These manuals provide recommended practices and methods by which many of the requirements of this Standard may be implemented.

Other references are listed in Annex I.

Annexes

There are nine annexes to this Standard. Annexes A, B, C, D, E, F, G, H and I are informative and not considered to be requirements of this Standard.

Purpose of this Standard

The purpose of this Standard is to provide requirements and guidelines for the design and installation of a data center or computer room. It is intended for use by designers who need a comprehensive understanding of the data center design, including the facility planning, the cabling system, and the network design. The standard will enable the data center design to be considered early in the building development process, contributing to the architectural considerations, by providing information that cuts across the multidisciplinary design efforts, promoting cooperation in the design and construction phases. Adequate planning during building construction or renovation is significantly less expensive and less disruptive than after the facility is operational. Data centers in particular can benefit from infrastructure that is planned in advance to support growth and changes in the computer systems that the data centers are designed to support.

This document presents an infrastructure topology for accessing and connecting the respective elements in the various cabling system configurations currently found in the data center environment. In order to determine the performance requirements of a generic cabling system, various telecommunications services and applications were considered. In addition, this document addresses the floor layout related to achieving the proper balance between security, rack density, and manageability.

The standard specifies a generic telecommunications cabling system for the data center and related facilities whose primary function is information technology. Such application spaces may be dedicated to a private company or institution, or occupied by one or more service providers to host Internet connections and data storage devices.

Data centers support a wide range of transmission protocols. Some of these transmission protocols impose length restrictions that are shorter than those imposed by this Standard. Consult standards, regulations, equipment vendors, and system service suppliers for: applicability, limitations, and ancillary requirements when applying specific transmission protocols. Consider consolidating standardized and proprietary cabling into a single structured cabling system.

Data centers can be categorized according to whether they serve the private domain ("enterprise" data centers) or the public domain (internet data centers, co-location data centers, and other service provider data centers). Enterprise facilities include private corporations, institutions or government agencies, and may involve the establishment of either intranets or extranets. Internet facilities include traditional telephone service providers, unregulated competitive service providers and related commercial operators. The topologies specified in this document, however, are intended to be applicable to both in satisfying their respective requirements for connectivity (internet access and wide-area communications), operational hosting (web hosting, file storage and backup, database management, etc.), and additional services (application hosting, content distribution, etc.). Failsafe power, environmental controls, fire suppression, system redundancy and security are also common requirements to facilities that serve both the private and public domain.

Stewardship

Telecommunications infrastructure affects raw material consumption. The infrastructure design and installation methods also influence product life and sustainability of electronic equipment life cycling. These aspects of telecommunications infrastructure impact our environment. Since building life cycles are typically planned for decades, technological electronic equipment upgrades are necessary. The telecommunications infrastructure design and installation process magnifies the need for sustainable infrastructures with respect to building life, electronic equipment life cycling and considerations of effects on environmental waste. Telecommunications designers are encouraged to research local building practices for a sustainable environment and conservation of fossil fuels as part of the design process.

See ANSI/TIA-4994 and TIA TSB-5046 for sustainability processes and guidelines.

Specification of criteria

Two categories of criteria are specified; mandatory and advisory. The mandatory requirements are designated by the word "shall"; advisory requirements are designated by the words "should", "may", or "desirable" which are used interchangeably in this Standard.

Mandatory criteria generally apply to protection, performance, administration and compatibility; they specify minimally acceptable requirements. Advisory criteria are presented when their attainment may enhance the general performance of the cabling system in all its contemplated applications.

A note in the text, table, or figure is used for emphasis or offering informative suggestions, or providing additional information.

Metric equivalents of US customary units

The dimensions in this Standard are metric or US customary with approximate conversion to the other.

Life of this Standard

This Standard is a living document. The criteria contained in this Standard are subject to revisions and updating as warranted by advances in building construction techniques and telecommunications technology.

1 SCOPE

This Standard specifies the minimum requirements for telecommunications infrastructure of data centers and computer rooms, including single tenant enterprise data centers and multi-tenant data centers. The topology specified in this document is intended to be applicable to any size data center.

2 NORMATIVE REFERENCES

The following standard contains provisions that, through references in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards published by them.

a) ANSI/ATIS 0600404:2005, *Network and Customer Installation Interfaces – DS3 and Metallic Interface Specification*

b) ANSI/NFPA 75-2017*, Standard for the Fire Protection of Information Technology Equipment®*

c) ANSI/TIA-568.0-D:2015 – *Generic Telecommunications Cabling for Customer Premises*

d) ANSI/TIA-568.1-D:2015 – *Commercial Building Telecommunications Infrastructure Standard*

e) ANSI/TIA-568-C.2:2009, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard*

f) ANSI/TIA-568.3-D:2016 – *Optical Fiber Cabling and Components Standard*

g) ANSI/TIA-568.4-D:2017 – *Broadband Coaxial Cable and Components Standard*

h) ANSI/TIA-569-D:2015 – *Telecommunications Pathways and Spaces*

i) ANSI/TIA-604-5-E:2015 – *FOCIS 5 – Fiber Optic Connector Intermateability Standard, Type MPO*

j) ANSI/TIA-604-10-B:2008 – *FOCIS 10 – Fiber Optic Connector Intermateability Standard, Type LC*

k) ANSI/TIA-604-18:2015 – *FOCIS 18 – Fiber Optic Connector Intermateability Standard, Type MPO-16*

l) ANSI/TIA-606-C:2017 – *Administration Standard for Telecommunications Infrastructure*

m) ANSI/TIA-607-C:2015 – *Telecommunications Bonding and Grounding (Earthing) for Customer Premises*

n) ANSI/TIA-758-B:2012 – *Customer-Owned Outside Plant Telecommunications Infrastructure Standard*

o) ANSI/TIA-862-B:2016 – *Structured Cabling Infrastructure Standard for Intelligent Building Systems*

p) ANSI/TIA-5017:2016 – *Telecommunications Physical Network Security Standard*

q) ANSI/TIA-5048:2017 – *Automated infrastructure management (AIM) systems – Requirements, data exchange and applications*

r) OSHA CFR 1926.441 – *Battery Rooms and Battery Charging*

s) Telcordia GR-63:2012 – *NEBS™ Requirements: Physical Protection*

t) Telcordia GR-3175:2014 – *Generic Requirements for Intrabuilding Coaxial Cable*

3 DEFINITION OF TERMS, ACRONYMS AND ABBREVIATIONS, AND UNITS OF MEASURE

3.1 General

The generic definitions in this clause have been formulated for use by the entire family of telecommunications infrastructure standards. Specific requirements are found in the normative clauses of this Standard.

3.2 Definition of terms

For the purposes of this Standard, the following definitions apply.

access floor: A system consisting of completely removable and interchangeable floor panels that are supported on adjustable pedestals or stringers (or both) to allow access to the area beneath.

access provider: The operator of any facility that is used to convey telecommunications signals to and from a customer premises.

access switch: A switch used to connect devices, such as servers, to a local area network.

administration: The method for labeling, identification, documentation and usage needed to implement moves, additions and changes of the telecommunications infrastructure.

aggregation switch: A switch that aggregates network traffic to and from access switches and that may also connect to network service devices (e.g., load balancers, network appliances, fire-walls).

backbone: A facility (e.g., pathway, cable or bonding conductor) for cabling Subsystem 2 and Cabling Subsystem 3.

backbone cable: See **backbone**.

blocking switch fabric: A switch fabric that does not have sufficient bandwidth to ensure that any port can communicate with any other port in the switch fabric at the full bandwidth capacity of either port.

bonding: The joining of metallic parts to form an electrically conductive path.

cabinet: A container that may enclose connection devices, terminations, apparatus, wiring, and equipment.

cable: An assembly of one or more insulated conductors or optical fibers, within an enveloping sheath.

cabling: A combination of all cables, jumpers, cords, and connecting hardware.

Cabling Subsystem 1: Cabling from the equipment outlet to Distributor A, Distributor B, or Distributor C.

Cabling Subsystem 2: Cabling between Distributor A and either Distributor B or Distributor C (if Distributor B is not implemented).

Cabling Subsystem 3: Cabling between Distributor B and Distributor C.

centralized cabling: A cabling configuration using a continuous cable, an interconnect, or a splice from an equipment outlet to a centralized cross-connect in Distributor B or Distributor C.

centralized switch fabric: A data center switch fabric architecture in which the switch fabric is implemented in a single centralized switch.

channel: The end-to-end transmission path between two points at which application-specific equipment is connected.

common equipment room (telecommunications): An enclosed space used for equipment and backbone interconnections for more than one tenant in a building or campus.

compartmentalization: creation of a physical barrier between two or more compartments which have separate fire suppression and cooling systems**.**

computer room: An architectural space whose primary function is to accommodate data processing equipment.

concurrently maintainable: The ability to have planned maintenance performed at any time on any path, equipment or component of the system without interrupting the operation of the system.

conduit: (1) A raceway of circular cross-section. (2) A structure containing one or more ducts.

NOTE: For the purposes of this Standard the term conduit includes electrical metallic tubing (EMT) or electrical non-metallic tubing (ENT).

conduit sizes: For the purposes of this Standard, conduit sizes are designated according to metric designator and trade size as shown below:

Table 1: Conduit sizes

Metric Designator	Trade Size
16	1/2
21	3/4
27	1
35	1 1/4
41	1 1/2
53	2
63	2 1/2
78	3
91	3 1/2
103	4
129	5
155	6

connecting hardware: A device providing mechanical cable terminations.

consolidation point: A connection facility within Cabling Subsystem 1 for interconnection of cables extending from building pathways to the equipment outlet.

cord (telecommunications): An assembly of cord cable with a plug on one or both ends.

core switch: A backbone switch at the highest hierarchical layer of a network.

cross-connect: A facility enabling the termination of cable elements and their interconnection or cross-connection.

cross-connection: A connection scheme between cabling runs, subsystems, and equipment using patch cords or jumpers that attach to connecting hardware on each end.

data center: A building or portion of a building whose primary function is to house a computer room and its support areas.

demarcation point: A point where the operational control or ownership changes.

dew point: The temperature to which air must be cooled (assuming constant air pressure and moisture content) to reach a relative humidity of 100% (i.e. saturation).

direct attach cabling: Cabling that provides a connection between equipment without any intervening connections. Note, in prior versions of this standard direct attach cabling was known as point-to-point cabling.

Distributor A: Optional connection facility in a hierarchical star topology that is cabled between the equipment outlet and Distributor B or Distributor C.

Distributor B: Optional intermediate connection facility in a hierarchical star topology that is cabled to Distributor C.

Distributor C: Central connection facility in a hierarchical star topology.

dry-bulb temperature: The temperature of air measured by a thermometer freely exposed to the air but shielded from radiation (e.g., sunlight, radiant heat) and moisture.

earthing: See grounding.

electromagnetic interference: Radiated or conducted electromagnetic energy that has an undesirable effect on electronic equipment or signal transmissions.

entrance point (telecommunications): The point of emergence for telecommunications cabling through an exterior wall, a floor, or from a conduit.

entrance room or space (telecommunications): A space in which the joining of inter or intra building telecommunications cabling takes place.

equipment cord: See **cord.**

equipment distribution area: The computer room space occupied by equipment racks or cabinets.

equipment outlet: Outermost connection facility in a hierarchical star topology.

equipment room (telecommunications): An environmentally controlled centralized space for telecommunications equipment that usually houses Distributor B or Distributor C.

external network interface: Interface between the computer room cabling and external cabling.

fat tree, fabric: A switch connection topology where each access switch is connected to every interconnection switch within the fabric.

fault tolerant: The ability to withstand a single fault

fiber optic: See **optical fiber**.

full-mesh, fabric: A switch connection topology where each switch is directly connected to all other switches within the mesh.

ground: A conducting connection, whether intentional or accidental, between an electrical circuit (e.g., telecommunications) or equipment and the earth, or to some conducting body that serves in place of earth.

grounding: The act of creating a ground.

grounding conductor: A conductor used to connect the grounding electrode to the building's main grounding busbar.

horizontal cabling: Cabling Subsystem 1.

horizontal cross-connect: Distributor A.

horizontal distribution area: A space in a data center where a horizontal cross-connect is located.

identifier: An item of information that links a specific element of the telecommunications infrastructure with its corresponding record.

infrastructure (telecommunications): A collection of those telecommunications components, excluding equipment, that together provide the basic support for the distribution of information within a building or campus.

interconnected mesh fabric: A switch connection topology in which pods, each containing a full-mesh fabric, are connected using interconnection switches.

interconnection: A connection scheme that employs connecting hardware for the direct connection of a cable to another cable without a patch cord or jumper, or employs a patch cord or jumper to make a connection between connecting hardware and equipment.

interconnection switch: A switch used to connect access switches, or lower level interconnection switches, in a fabric.

intermediate cross-connect: Distributor B.

intermediate distribution area: A space in a data center where an intermediate cross-connect is located.

jumper: 1) An assembly of twisted pairs without connectors, used to join telecommunications circuits/links at the cross-connect. 2) An assembly of optical fiber cable with a connector on each end (often referred to as a cord).

leaf and spine switch fabric architecture: See **fat tree, fabric**.

leaf switch: An access switch in a leaf and spine switch fabric architecture.

link: A transmission path between two points, not including equipment and cords.

liquidtight: Impervious to moisture ingress.

main cross-connect: Distributor C.

main distribution area: The space in a data center where the main cross-connect is located**.**

mechanical room: An enclosed space serving the needs of mechanical building systems.

media (telecommunications): Wire, cable, or conductors used for telecommunications.

modular jack: A female telecommunications connector that may be keyed or unkeyed and may have 6 or 8 contact positions, but not all the positions need be equipped with jack contacts.

multimode optical fiber: An optical fiber that carries many paths of light.

non-blocking switch fabric: A switch fabric that has sufficient bandwidth to ensure that any port can communicate with any other port in the switch fabric at the full bandwidth capacity of either port.

optical fiber: Any filament made of dielectric materials that guides light.

optical fiber cable: An assembly consisting of one or more optical fibers.

over-subscribe (bandwidth): The assignment of more traffic to a link than the bandwidth capacity of the link.

patch cord: A cord used to establish connections on a patch panel.

patch panel: A connecting hardware system that facilitates cable termination and cabling administration using patch cords.

pathway: A facility for the placement of telecommunications cable.

plenum: A compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system.

pod, data center: A modular subset of the data center.

port: A connection point for one or more conductors or fibers.

port extender: A device that provides additional ports to the controlling switch to which it is connected.

post-tensioned concrete: A type of reinforced concrete construction in which the embedded steel members are first put under tension, the concrete poured and allowed to harden, and the tension of the steel members released causing compression of the concrete.

post-tension floor: A floor that is constructed of post-tensioned concrete.

private branch exchange: A private telecommunications switching system.

pull box: A housing located in a pathway run used to facilitate the placing of wire or cables.

rack: Supporting frame equipped with side mounting rails to which equipment and hardware are mounted.

radio frequency interference: Electromagnetic interference within the frequency band for radio transmission.

return loss: A ratio expressed in dB of the power of the outgoing signal to the power of the reflected signal.

screen: An element of a cable formed by a shield.

service provider: The operator of any service that furnishes telecommunications content (transmissions) delivered over access provider facilities.

sheath: See **cable sheath**.

shield: 1) A metallic layer placed around a conductor or group of conductors. 2) The cylindrical outer conductor with the same axis as the center conductor that together form a coaxial transmission line.

single-mode optical fiber: An optical fiber that carries only one path of light.

space (telecommunications): An area used for housing the installation and termination of telecommunications equipment and cable.

spanning tree protocol: Link management protocol that provides path redundancy while preventing un-desirable loops in the network.

spine switch: An interconnection switch in a leaf and spine switch fabric architecture.

splice: A joining of conductors, meant to be permanent.

star topology: A topology in which telecommunications cables are distributed from a central point.

switch fabric: A network topology where devices connect with one another using network switches over multiple paths.

telecommunications: The transmission and reception of information by cable, radio, optical or other electromagnetic systems.

telecommunications entrance point: See **entrance point (telecommunications)**.

telecommunications entrance room or space: See **entrance room or space (telecommunications)**.

telecommunications equipment room: See **equipment room (telecommunications)**.

telecommunications infrastructure: See **infrastructure (telecommunications)**.

telecommunications media: See **media (telecommunications)**.

telecommunications room: An enclosed architectural space for housing telecommunications equipment, cable terminations, or cross-connect cabling.

telecommunications space: See **space (telecommunications)**.

termination block: A connecting hardware system that facilitates cable termination and cabling administration using jumpers.

topology: The physical or logical arrangement of a telecommunications system.

uninterruptible power supply: A buffer between utility power or other power source and a load that requires continuous precise power.

virtual switch fabric: A switch connection topology in which a switch fabric is formed by interconnecting multiple switches to form a single large virtual switch.

wire: An individually insulated solid or stranded metallic conductor.

wireless: The use of radiated electromagnetic energy (e.g., radio frequency and microwave signals, light) traveling through space to transport information.

zone distribution area: A space in a data center where an equipment outlet or a consolidation point is located.

3.3 Acronyms and abbreviations

AHJ	authority having jurisdiction
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BNC	bayonet Neill-Concelman
CCTV	closed-circuit television
CER	common equipment room
CP	consolidation point
CPU	central processing unit
CSA	Canadian Standards Association International
DSX	digital signal cross-connect
EDA	equipment distribution area
EMS	energy management system
ENI	external network interface
EO	equipment outlet
HC	horizontal cross-connect
HDA	horizontal distribution area
HVAC	heating, ventilation and air conditioning
IC	intermediate cross-connect
ICT	Information and communications technology
IDA	intermediate distribution area
IDC	insulation displacement contact
KVM	keyboard, video, mouse
LAN	local area network
MC	main cross-connect
MDA	main distribution area
MPO	Multi-fiber Push On
NEC®	National Electrical Code®
NEMA	National Electrical Manufacturers Association

NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PBX	private branch exchange
PDU	power distribution unit
SAN	storage area network
SDH	synchronous digital hierarchy
SONET	synchronous optical network
STM	synchronous transport model
TIA	Telecommunications Industry Association
TNC	threaded Neill-Concelman
TR	telecommunications room
UL	Underwriters Laboratories Inc.
UPS	uninterruptible power supply
WAN	wide area network
ZDA	zone distribution area

3.4 Units of measure

A	ampere
dB	decibel
°C	degrees Celsius
°F	degrees Fahrenheit
ft	feet, foot
in	inch
kb/s	kilobit per second
km	kilometer
kPa	kilopascal
kVA	kilovoltamp
kW	kilowatt
lbf	pound-force
m	meter
MHz	megahertz
mm	millimeter
nm	nanometer
μm	micrometer (micron)

4 DATA CENTER DESIGN OVERVIEW

4.1 General

The following information and recommendations are intended to enable an effective implementation of a data center design by identifying the appropriate actions to be taken in each step of the planning and design process. The design specific details are provided in the subsequent clauses and annexes.

The steps in the design process described below apply to the design of a new data center or the expansion of an existing data center. It is essential for either case that the design of the telecommunications cabling system, equipment floor plan, electrical plans, architectural plan, HVAC, security, and lighting systems be coordinated. Ideally, the process should be:

a) Estimate equipment telecommunications, space, power, and cooling requirements of the data center at full capacity. Anticipate future telecommunications, power, and cooling trends over the lifetime of the data center.

b) Provide space, power, cooling, security, floor loading, grounding, electrical protection, and other facility requirements to architects and engineers. Provide requirements for operations center, loading dock, storage room, staging areas and other support areas.

c) Coordinate preliminary data center space plans from architect and engineers. Suggest changes as required.

d) Create an equipment floor plan including placement of major rooms and spaces for entrance rooms, main distribution areas, intermediate distribution areas, horizontal distribution areas, zone distribution areas and equipment distribution areas. Provide expected power, cooling, and floor loading requirements for equipment to engineers. Provide requirements for telecommunications pathways.

e) Obtain an updated plan from engineers with telecommunications pathways, electrical equipment, and mechanical equipment added to the data center floor plan at full capacity.

f) Design telecommunications cabling system based on the needs of the existing and planned future equipment to be located in the data center.

The data center shall meet the requirements of the AHJ and should follow NFPA 75 or other data center fire protection standard applicable for the country in which the data center is built.

4.2 Relationship of data center spaces to other building spaces

Figure 2 illustrates the major spaces of a typical data center and how they relate to each other and the spaces outside of the data center. See clause 6 for information concerning the telecommunications spaces within the data center.

This Standard addresses telecommunications infrastructure for the data center spaces, which is the computer room and its associated support spaces.

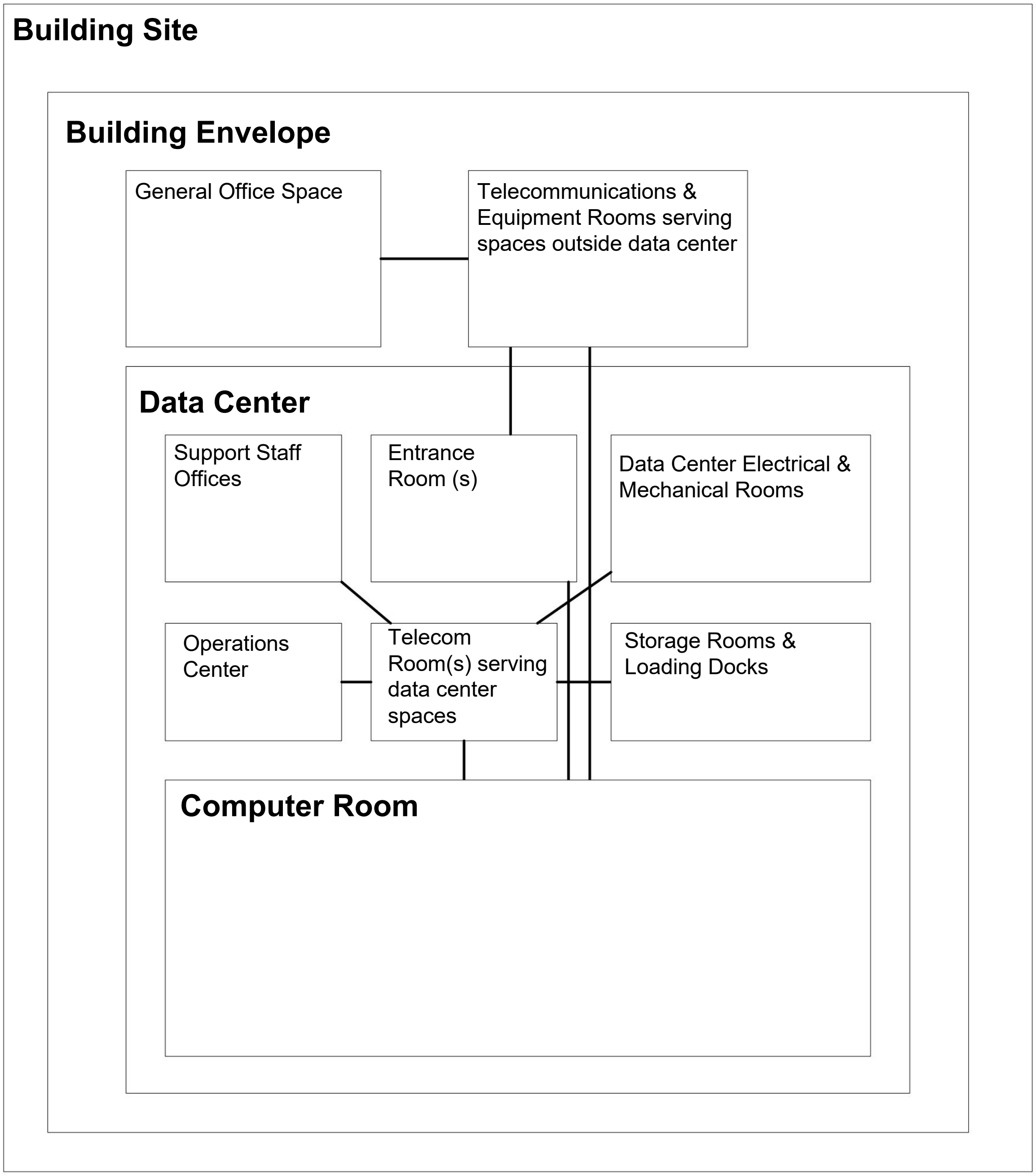


Figure 2: Relationship of spaces in a data center

4.3 Availability and Security

This Standard includes information for availability and security of the data center facility infrastructure. Higher ratings correspond to higher availability and security. Annex F of this Standard provides detailed information. Refer to ANSI/TIA-5017 for information regarding physical security for telecommunications infrastructure.

It is important to understand that certain intentional or accidental events, or acts of nature, pose a risk to the operation of data centers. It is important for the data center designer, administrator and manager to both assess and try to mitigate the risk to their facilities these events pose, as well as make contingency plans. The designer should provide a risk assessment, and recommend ways to manage that risk, whether intentional, accidental or forces of nature. Risk management can take many forms including:

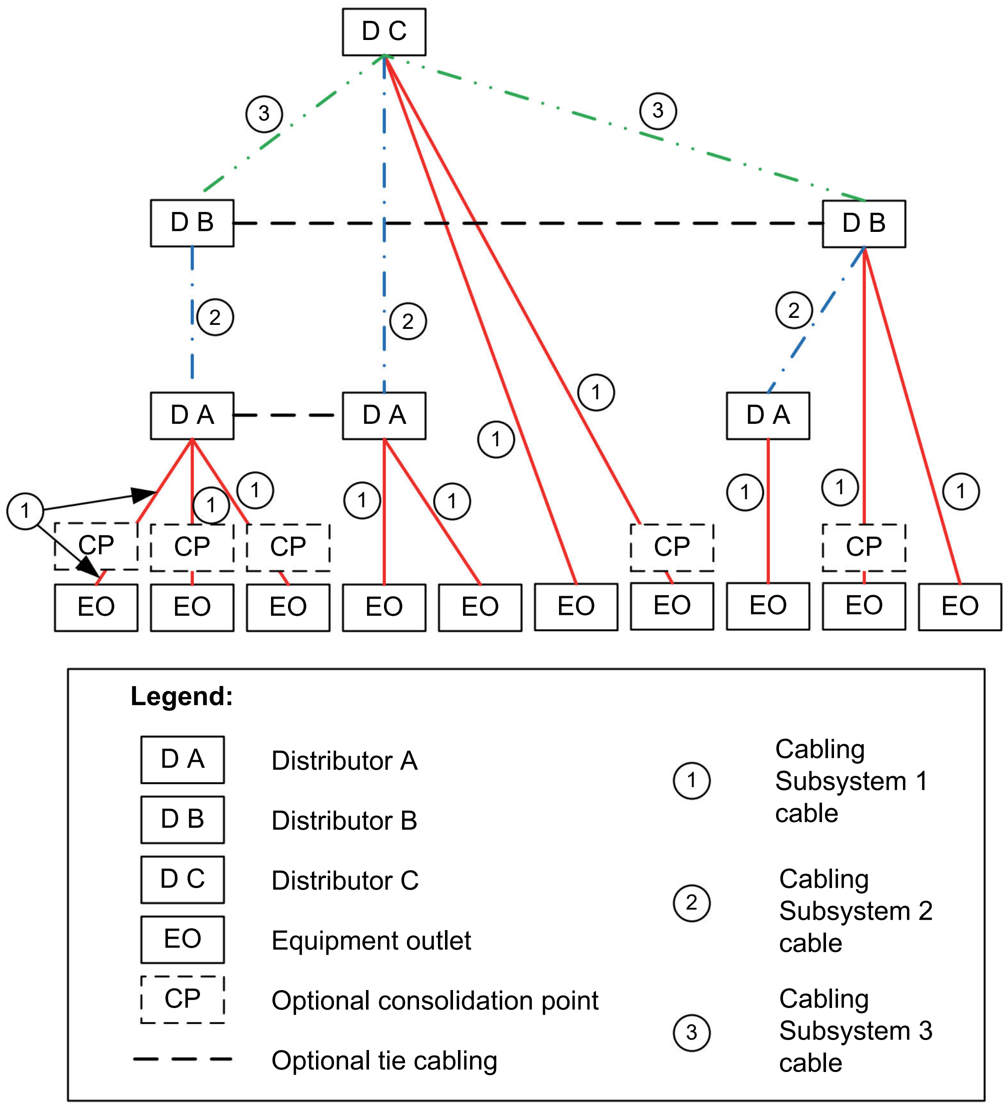
a) a risk model to demonstrate the event probability based on industry accepted models (e.g., earthquake or lightning);
b) risk avoidance (separation, protection, security, etc.);
c) resiliency and redundancy, at both a systems and facilities level; and
d) replicating applications and data between data centers.

4.4 Consideration for involvement of professionals

Data centers are designed to support the requirements of large quantities of computer and telecommunications equipment. Therefore, telecommunications and information technology professionals and specifications should be involved in the design of the data center from its inception. In addition to the space, environmental, adjacency, and operational requirements for the computer and telecommunications equipment, data center designs need to address the requirements of the telecommunications pathways and spaces specified in this Standard.

5 DATA CENTER CABLING SYSTEM INFRASTRUCTURE

This Standard establishes a structure for data center cabling system based on the generic cabling system structure in ANSI/TIA-568.0-D.



NOTE – All elements shown represent cables and connecting hardware, not spaces or pathways.

Figure 3: Functional elements of generic cabling topology

Figure 3 provides a representation of the functional elements that comprise a generic cabling system. It depicts the relationship between the elements and how they may be configured to create a total system. The functional elements are “equipment outlets,” “distributors," and "cabling subsystems", which together comprise a generic telecommunications cabling system.

Figure 4 shows examples of interconnections and cross-connections for Distributor A. Similar configurations may be present for Distributor B and Distributor C.

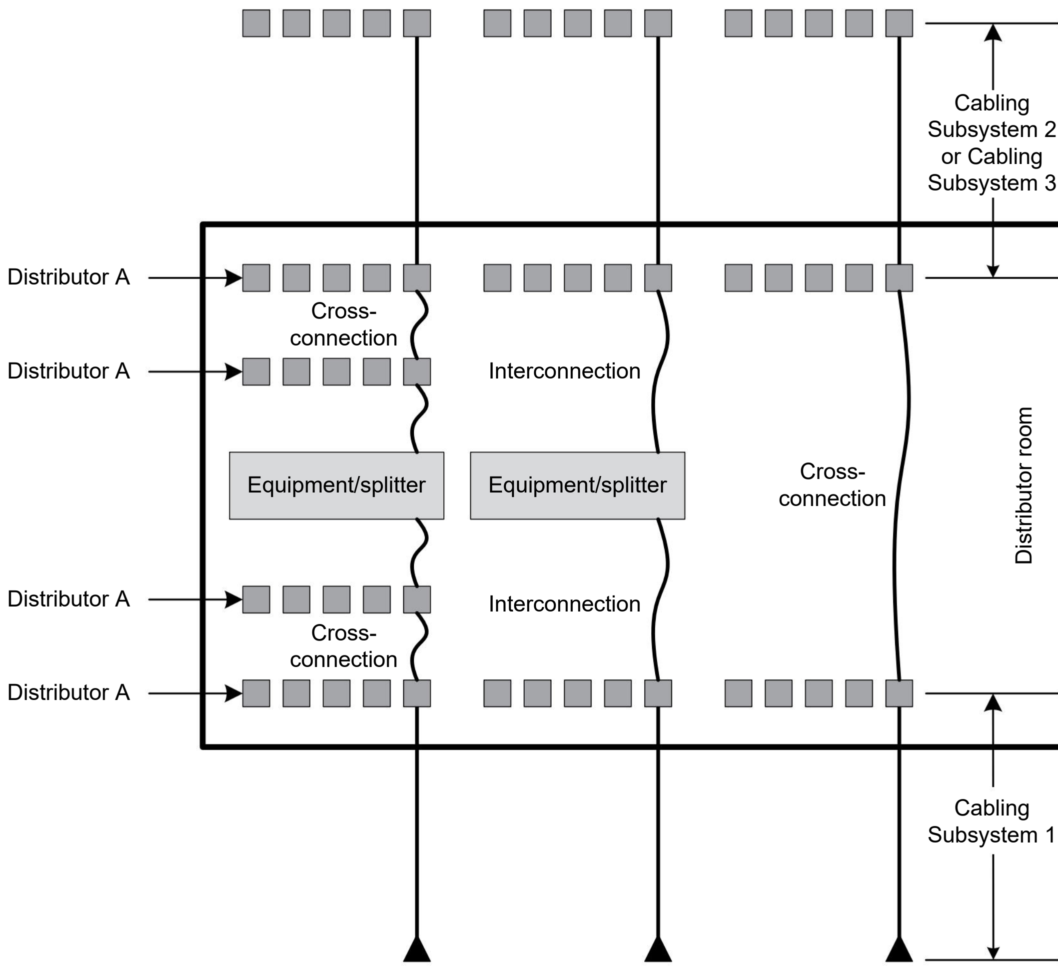


Figure 4: Examples of interconnections and cross-connections for Distributor A

Figure 5 illustrates a representative model for the various functional elements that comprise a cabling system for a data center. It depicts the relationship between the elements and how they are configured to create the total system.

The basic elements of the data center cabling system structure are the following:

a) Horizontal cabling (Cabling Subsystem 1 – see clause 7.3)

b) Backbone cabling (Cabling Subsystem 2 and Cabling Subsystem 3 – see clause 7.4)

c) Cross-connect in the entrance room or main distribution area (Distributor C, Distributor B or Distributor A)

d) Main cross-connect (MC) in the main distribution area (Distributor C or could also be Distributor B or Distributor A)

e) Optional intermediate cross-connect (IC) in the intermediate distribution area (Distributor B)

f) Horizontal cross-connect (HC) in the telecommunications room, horizontal distribution area or main distribution area (Distributor A or could also be Distributor B or Distributor C)

g) Consolidation point in the zone distribution area (optional)

h) Equipment outlet (EO) located in the equipment distribution area or zone distribution area

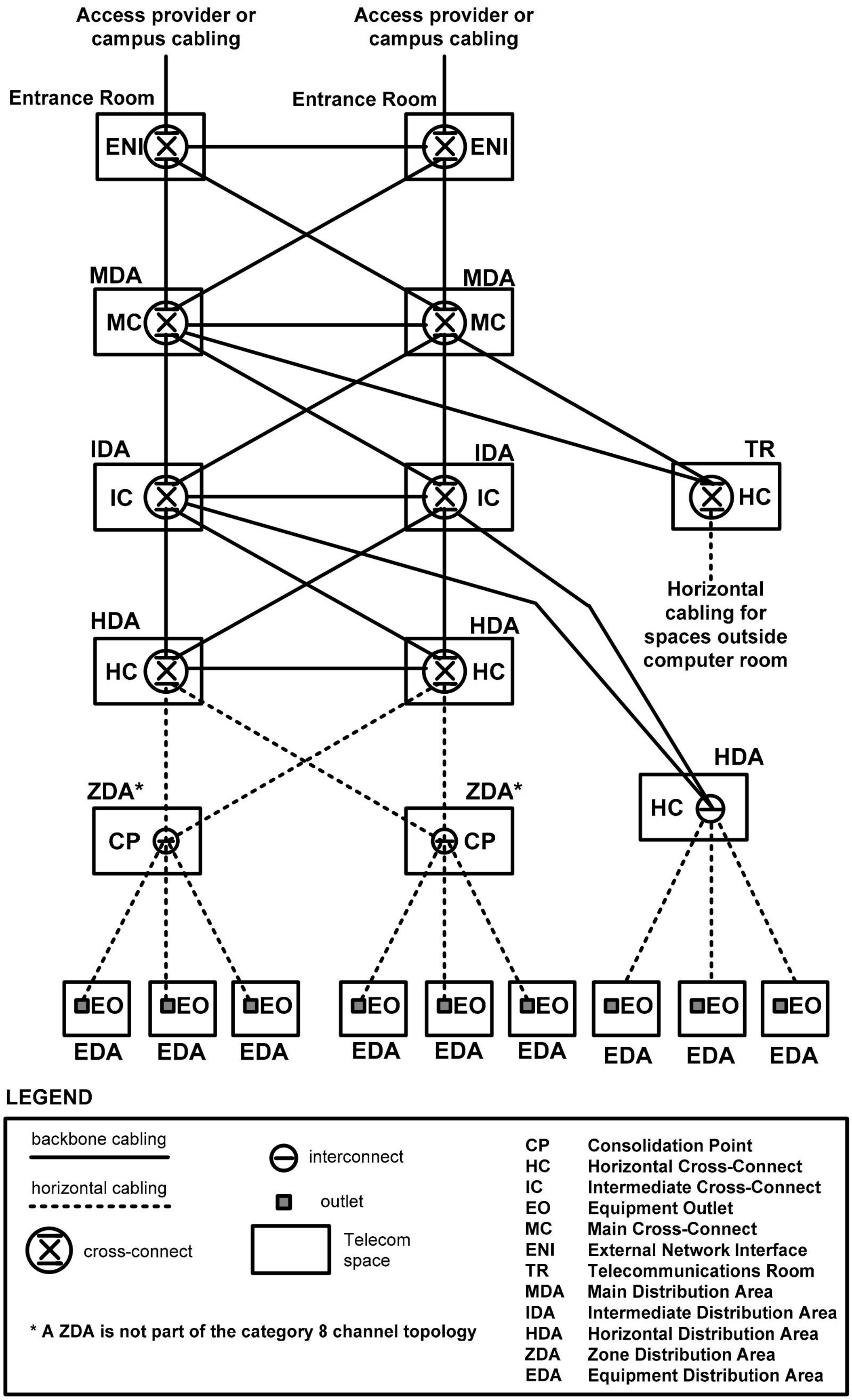


Figure 5: Example of a typical data center topology

6 DATA CENTER TELECOMMUNICATIONS SPACES AND RELATED TOPOLOGIES

6.1 General

The data center requires spaces dedicated to supporting the telecommunications infrastructure. Telecommunications spaces shall be dedicated to support telecommunications cabling and equipment. Typical spaces found within a data center generally include the entrance room, main distribution area (MDA), intermediate distribution area (IDA), horizontal distribution area (HDA), zone distribution area (ZDA) and equipment distribution area (EDA). With the exception of the MDA and EDA, not all of these spaces may be present within the data center. These spaces shall be sized to accommodate the anticipated end-state size and demand forecast for all data center phases. These spaces should also be planned to provide for growth and transition to evolving technologies. These spaces may or may not be walled off or otherwise separated from the other computer room spaces.

6.2 Data center structure

6.2.1 Major elements

The data center telecommunications spaces include the entrance room, main distribution area (MDA), intermediate distribution area (IDA), horizontal distribution area (HDA), zone distribution area (ZDA) and equipment distribution area (EDA).

The entrance room is the space used for the interface between data center structured cabling system and inter-building cabling, for both access provider and customer-owned cabling. This space includes the access provider demarcation hardware and access provider equipment. The entrance room may be located outside the computer room if the data center is in a building that includes general purpose offices or other types of spaces outside the data center. The entrance room may also be outside the computer room for improved security, as it avoids the need for access provider technicians to enter the computer room. Data centers may have multiple entrance rooms to provide additional redundancy or to avoid exceeding maximum cable lengths for access provider-provisioned circuits.

The entrance room interfaces with the computer room through the MDA. In some cases, the secondary entrance rooms may have cabling to IDAs or HDAs to avoid exceeding maximum cable lengths for access provider-provisioned circuits. The entrance room may be adjacent to or combined with the MDA.

The MDA includes the main cross-connect (MC), which is the central point of distribution for the data center structured cabling system and may include a horizontal cross-connect (HC) when equipment areas are served directly from the MDA. This space is inside the computer room; it may be located in a dedicated room in a multi-tenant data center for security. Every data center shall have at least one MDA. The computer room core routers, core LAN switches and core SAN switches are often located in the MDA, because this space is the hub of the cabling infrastructure for the data center. Access provider provisioning equipment is often located in the MDA rather than in the entrance room to avoid the need for a second entrance room due to circuit length restrictions.

The MDA may serve one or more IDAs, HDAs, and EDAs within the data center and one or more telecommunications rooms located outside the computer room space to support office spaces, operations center and other external support rooms.

The IDA may serve one or more HDAs and EDAs within the data center, and one or more telecommunications rooms located outside the computer room space.

The HDA is used to serve the EDAs when the HC is not located in the MDA or an IDA. Therefore, when used, the HDA may include the HC, which is the distributor for cabling to the EDAs. The HDA is inside the computer room, but may be located in a dedicated room within the computer room for additional security. The HDA typically includes LAN switches, SAN switches, and Keyboard/Video/Mouse (KVM) switches for the end equipment located in the EDAs. A data center may have computer room spaces located on multiple floors with each floor being serviced by its own HC. Some data centers may require no HDAs, as the entire computer room may be able to be supported from the MDA. However, a typical data center will have several HDAs.

The EDA is the space allocated for end equipment, including computer systems and telecommunications equipment (e.g., servers, mainframe, and storage arrays). These areas shall not serve the purposes of an entrance room, MDA, IDA, or HDA.

There may be an optional interconnection within a ZDA that is called a consolidation point (see figure 5). This consolidation point is between the horizontal cross-connect and the equipment outlet to facilitate moves, adds, and changes.

6.2.2 Basic data center topology

The basic data center includes a single entrance room, possibly one or more telecommunications rooms, one MDA, and several HDAs. Figure 6 illustrates the basic data center topology.

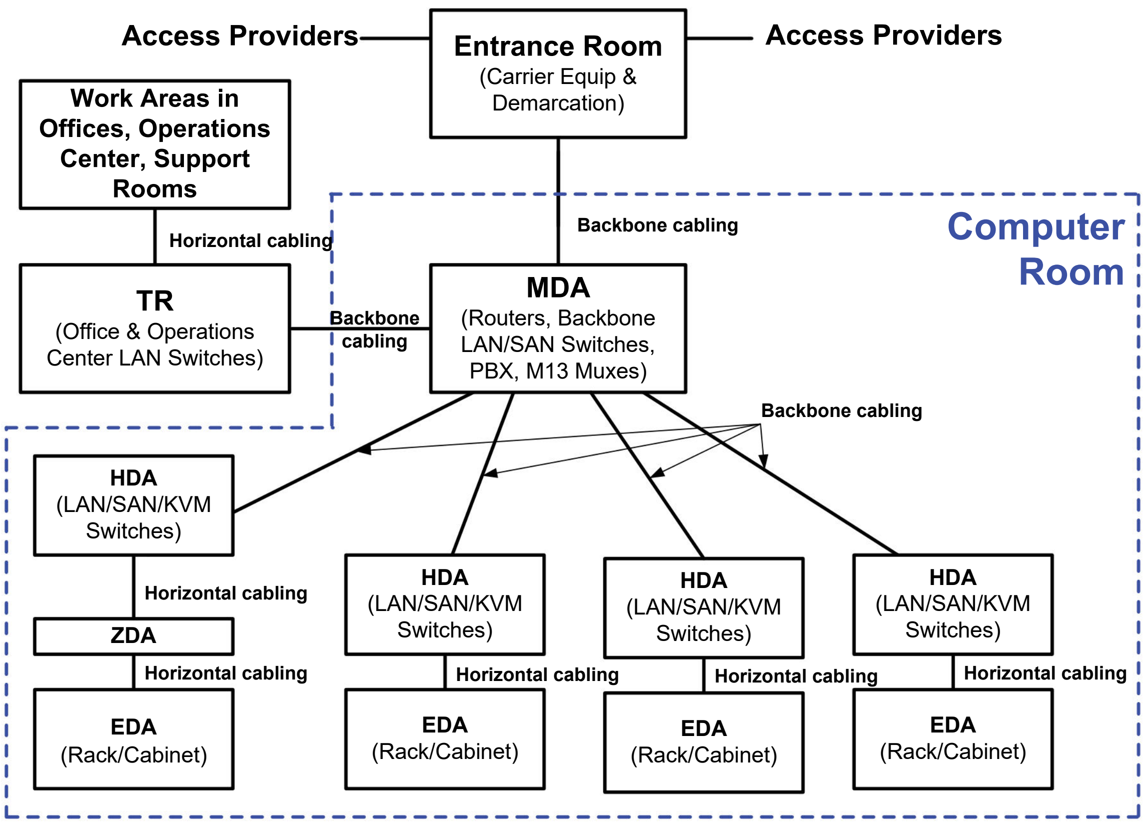


Figure 6: Example of a basic data center topology

6.2.3 Reduced data center topologies

Data center designers can consolidate the main cross-connect, and horizontal cross-connect in a single MDA, possibly as small as a single cabinet or rack. The telecommunications room for cabling to the support areas and the entrance room may also be consolidated into the MDA in a reduced data center topology. The reduced data center topology is illustrated in figure 7.

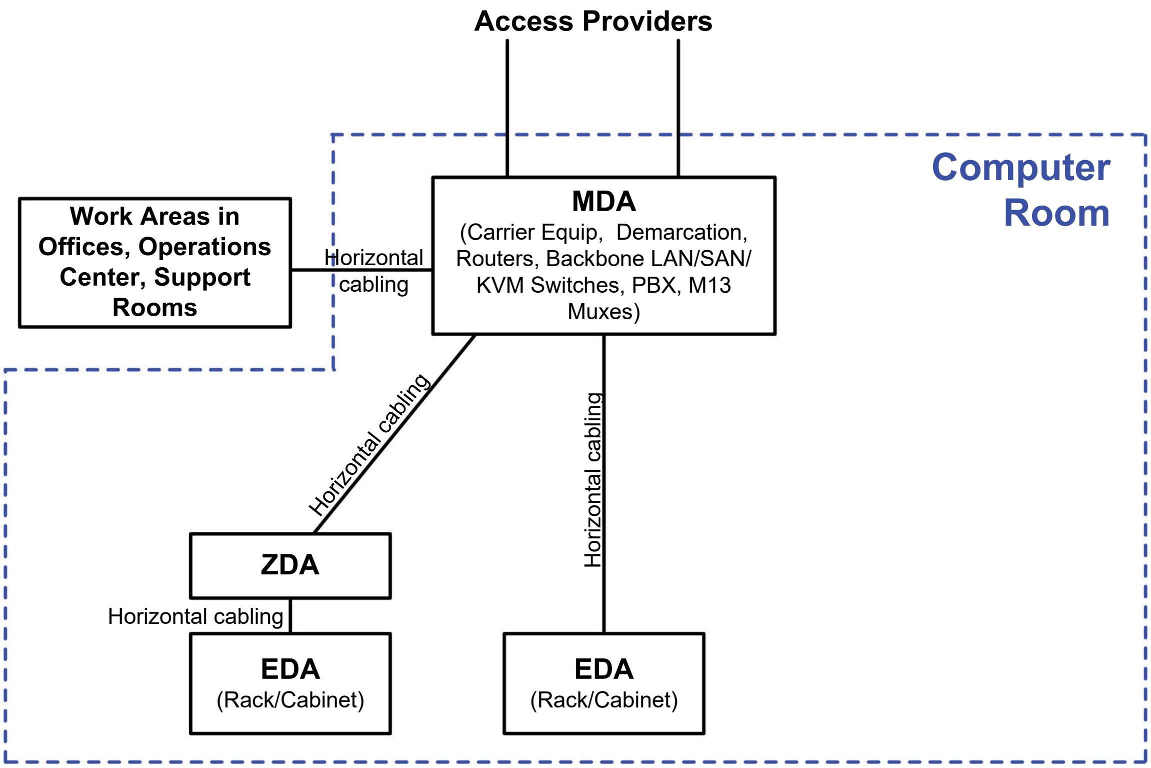


Figure 7: Example of a reduced data center topology

6.2.4 Distributed data center topologies

Large data centers, such as data centers located on multiple floors or in multiple rooms, may require intermediate cross-connects located in IDAs. Each room or floor may have one or more IDAs.

Multiple telecommunications rooms may be required for data centers with large or widely separated office and support areas.

In very large data centers, circuit length restrictions may require multiple entrance rooms. The data center topology with multiple entrance rooms and IDAs is shown in Figure 8. The primary entrance room shall not have direct connections to IDAs and HDAs. Although cabling from the secondary entrance room directly to the IDAs and HDAs is not common practice or encouraged, it is allowed to meet certain circuit length limitations and redundancy needs.

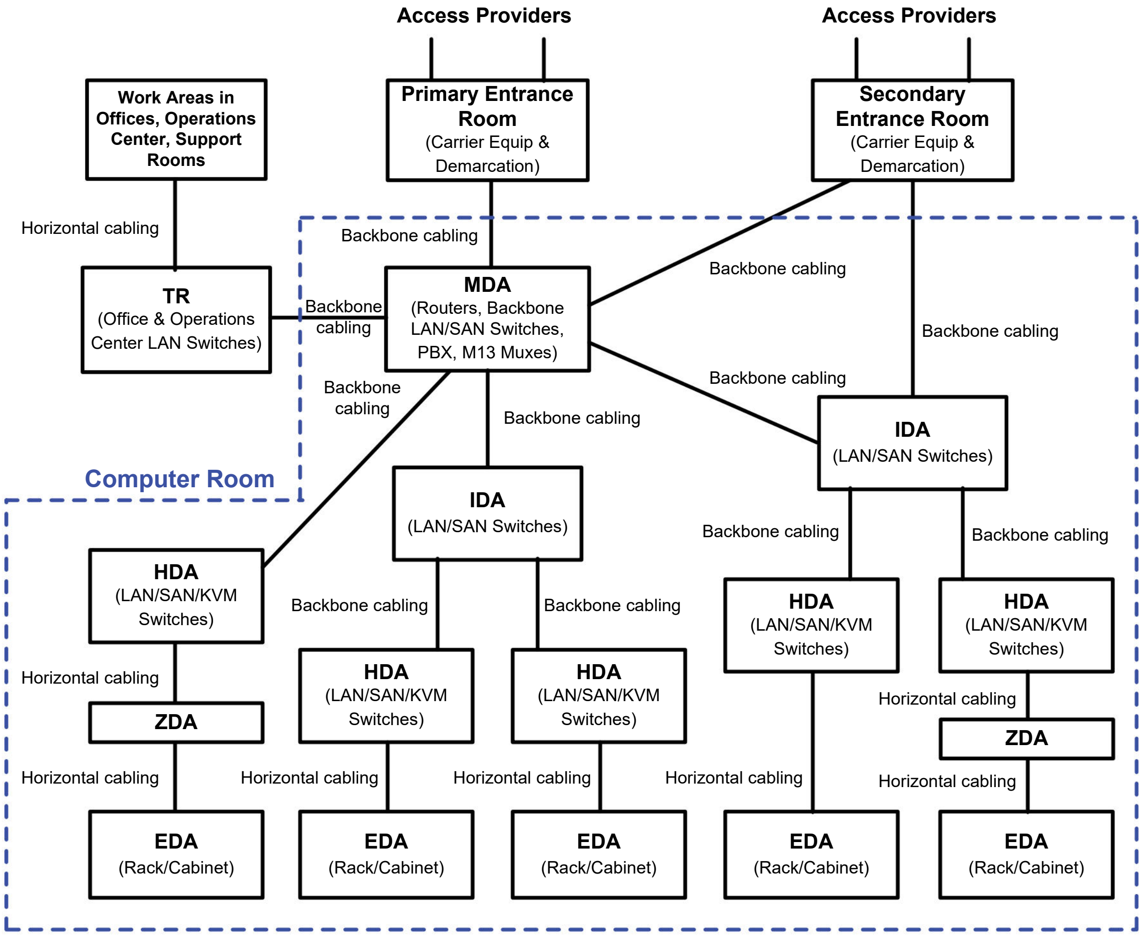


Figure 8: Example of a distributed data center topology with multiple entrance rooms

6.2.5 Topologies for broadband coaxial cabling

See ANSI/TIA-568.4-D for broadband coaxial cabling system topologies that can be used within data centers.

6.3 Energy efficient design

6.3.1 General

Energy efficiency should be considered in the design of the data center. Clause 6.3.2 provides recommendations for design of telecommunications cabling, pathways, and spaces that can improve energy efficiency. Other methods involving other aspects of the data center design are described in other publications, including the following documents:

- ASHRAE, Best Practices for Datacom Facility Energy Efficiency, Second Edition (2009)
- ASHRAE, Design Considerations for Data and Communications Equipment Centers, Second Edition (2009)
- ASHRAE, Thermal Guidelines for Data Processing Environments, Fourth Edition, 2015
- European Commission, 2017 Best Practices for EU Code of Conduct on Data Centres, Version 8.1.0 (2017)

- European Commission, European Code of Conduct on Data Centre Energy Efficiency, Introductory guide for applications 2016, Version 3.1.2

6.3.2 Energy efficiency recommendations

6.3.2.1 General

By their nature, data centers consume large amounts of energy, most of which is converted to heat, requiring serious consideration to cooling efficiencies. There is no single thermal management architecture that is most energy efficient for all installations. Critical factors unique to the customer, application, and environment should be carefully evaluated in the start-up and operational analysis.

6.3.2.2 Telecommunications cabling

Overhead telecommunications cabling may improve cooling efficiency and is a best practice where ceiling heights permit because it can substantially reduce airflow losses due to airflow obstruction and turbulence caused by under floor cabling and cabling pathways. See ANSI/TIA-569-D for additional guidance regarding overhead pathways (e.g., structural load).

If telecommunications cabling is installed in an under floor space that is also used for cooling, under floor air obstructions can be reduced by:

- using network and cabling designs (e.g., top-of-rack switching) that require less cabling;
- selecting cables with smaller diameters to minimize the volume of under floor cabling;
- utilizing higher strand count optical fiber cables instead of several lower count optical fiber cables to minimize the volume of under floor cabling;
- designing the cabling pathways to minimize adverse impact on under floor airflow (e.g., routing cabling in hot aisles rather than cold aisles so as not to block airflow to ventilated tiles on cold aisles);
- designing the cabling layout such that the cabling routes are opposite to the direction of air flow so that at the origin of airflow there is the minimal amount of cabling to impede flow (see figure 9 for examples); and
- properly sizing pathways and spaces to accommodate cables with minimal obstruction (e.g., shallower and wider trays).

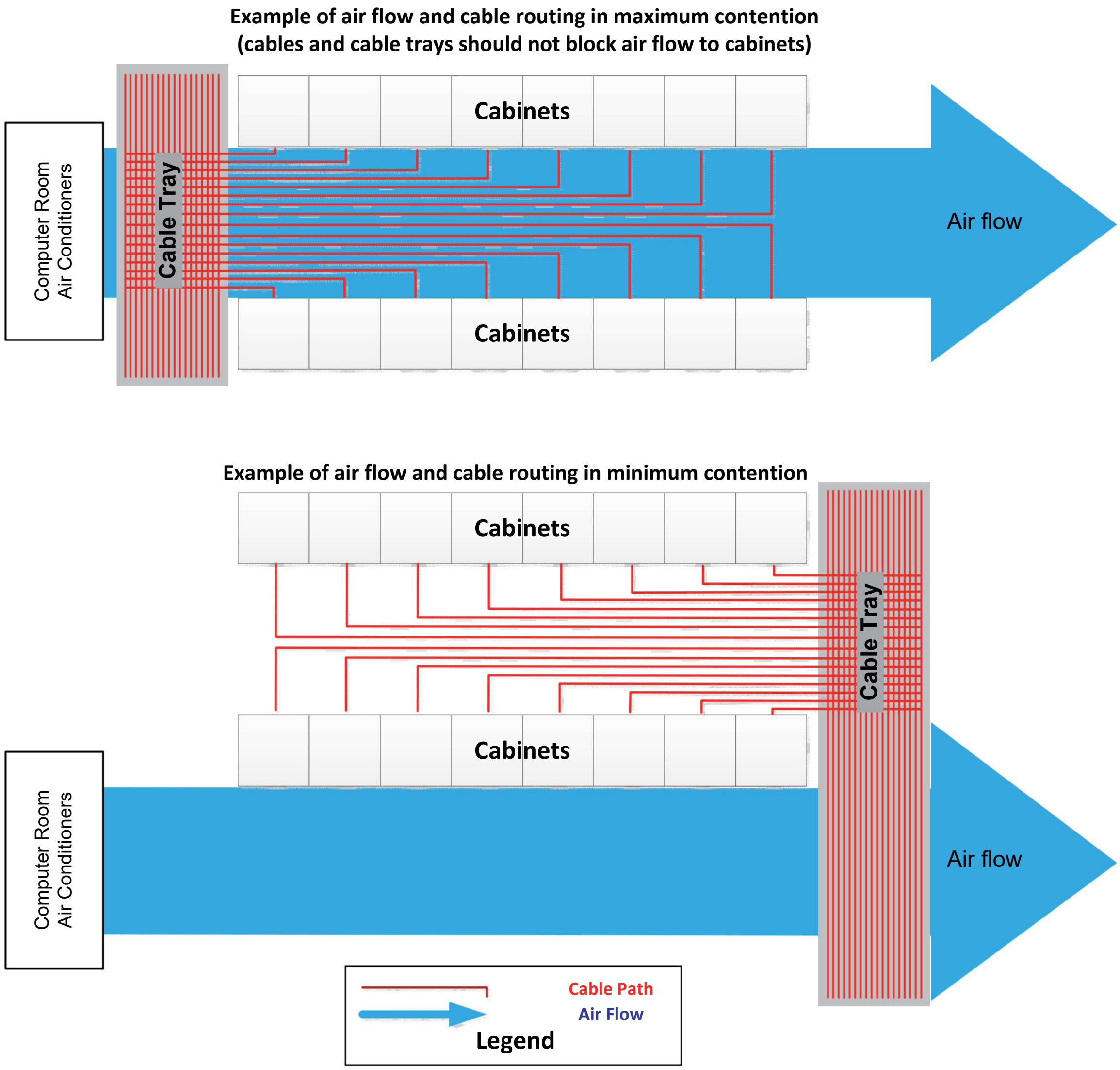


Figure 9: Examples of routing cables and air flow contention

Routing of telecommunications cabling within cabinets, racks, and other enclosure systems should not hamper the proper cooling of the equipment within the enclosures (e.g., avoid routing of cabling in front of vents). Sufficient airflow as required by the equipment manufacturer shall be maintained.

In all cases, change management procedures should be in place and should include the removal of abandoned cable in accordance with the best practices or the AHJ. This assures pathways remain neat so as to not create a weight issue overhead or air dams in under floor systems.

6.3.2.3 Telecommunications pathways

Telecommunications pathways should be placed in such a manner as to minimize disruption to airflow to and from equipment. For example, if placed under the access floor they should not be placed under ventilated tiles or where they disrupt the flow of air into or out of air conditioning equipment.

Consider computational fluid dynamics (CFD) models for large data centers to optimize location of telecommunications pathways, air conditioning equipment, equipment enclosures, air return, air vents, and ventilated tiles.

6.3.2.4 Telecommunications spaces

Consider use of enclosures or enclosure systems that improve cooling efficiency:

- cabinets with isolated air-supply;
- cabinets with isolated air-return;
- cabinets with in-cabinet cooling systems;
- hot-aisle containment or cold-aisle containment systems.

Routing of cabling and cable pathways should not compromise the efficiency of the enclosure or enclosure system. For example, cable openings in the enclosure or enclosure system should use brushes or grommets to minimize loss of air.

Commercially produced hardware and accessories specifically intended to prevent cold and hot air from mixing should be installed to improve energy efficiency. This may include:

- Blanking panels in unused rack unit positions
- Blanks in open port or module locations in patch panels
- Angled covers above and below angled patch panels or a group of continuous angled patch panels
- Panels, seals, and grommets to prevent air bypass between the cabinet rails and the side of the cabinets
- Seals between the floor and the bottom of the cabinets (front, side, and rear depending on the containment and cabinet design)
- Seals or side panels between cabinets with different front rail depths.

Equipment with different environmental requirements should be segregated into different spaces to allow equipment with less restrictive environmental requirements to be operated in spaces in a more energy-efficient environment.

Consider allocating and designing separate spaces dedicated to high density equipment so that the entire data center is not powered and cooled for the equipment with the greatest energy demands. It is recommended to use a cooling system that is able to vary the volume of air as needed.

Equipment should match the airflow design for the enclosures and computer room space in which they are placed. This generally means that equipment should be mounted in cabinets/racks with air intakes facing the cold-aisle and air exhausts facing the hot-aisle. Equipment with non-standard airflow may require specially designed enclosures or air baffles to avoid disruption of proper air flow.

Cabinets and racks should be provisioned with power strips that permit monitoring of power and cooling levels to ensure that enclosures do not exceed designed power and cooling levels.

Use energy efficient lighting and lighting schemes (see 6.4.2.5).

Avoid exterior windows and sky lights in computer rooms and other environmentally controlled telecommunications spaces.

Consider operation and design practices that minimize the need to cool unneeded equipment and spaces.

- Build the computer room in phases or zones, only building and occupying spaces as needed.
- In occupied data centers, institute a process to identify and remove equipment that is no longer needed or to identify and consolidate (e.g., virtualize) underutilized equipment.
- Install monitoring equipment and perform periodic reporting of total data center energy use and energy use of individual systems such as power distribution units, air conditioning units, and IT equipment cabinets/racks.

- Consider air baffles and temporary room dividers that can be moved and adjusted as needed. Any temporary room dividers shall not create a code violation.

6.4 Common requirements for computer rooms and entrance rooms

6.4.1 General

The requirements of these sections apply to computer rooms, entrance rooms, and if they are separate rooms – the rooms containing MDAs, IDAs, and HDAs.

The rooms shall meet the requirements for distributor rooms in ANSI/TIA-569-D with additional requirements, exceptions and allowances as specified in 6.4 through 6.11.

6.4.2 Architectural design

6.4.2.1 Location

The room should not have exterior windows, as exterior windows increase heat load and reduce security.

6.4.2.2 Size

The room shall be sized to meet the known requirements of specific equipment including proper clearances; this information can be obtained from the equipment provider(s). Sizing should include projected future as well as present requirements. See Annex D regarding data center space considerations.

6.4.2.3 Guidelines for other equipment

UPS containing flooded-cell batteries should be located in a separate room.

6.4.2.4 Ceiling height

The minimum height of the room shall be 2.6 m (8.5 ft) from the finished floor to any obstruction such as sprinklers, lighting fixtures, overhead cable tray or cameras. Cooling requirements or racks/cabinets taller than 2.13 m (7 ft) may dictate higher ceiling heights. A minimum of 460 mm (18 in) clearance shall be maintained from water sprinkler heads.

6.4.2.5 Lighting

Lighting fixtures should be located above aisles between cabinets rather than directly above cabinets or overhead cable pathway systems.

Emergency lighting and signs shall be properly placed per AHJ such that an absence of primary lighting will not hamper emergency exit.

It is recommended that a three-level lighting protocol be used in data centers depending on human occupancy:

- **Level 1:** data center unoccupied - lighting should be sufficient to allow effective use of video surveillance equipment.
- **Level 2:** initial entry into the data center - motion sensors should be used to activate lights in the immediate area of entry and be programmed to illuminate aisles and passageways. Sufficient lighting should be provided to allow safe passage through the space and to permit identification via security cameras.
- **Level 3:** occupied space - when the data center is occupied for purposes of maintenance or interaction with equipment, lighting shall be 500 lux in the horizontal plane and 200 lux in the vertical plane, measured 1 m (3 ft) above the finished floor in the middle of all aisles between cabinets. In data centers larger than 230 m^2 (2500 ft^2) zone lighting is recommended that provides Level 3 in the immediate area of work and Level 2 in all other zones.

- **Optional override**: lighting in all zones at level 3.

To allow improved energy efficiency and control, energy efficient lighting (e.g., LED) should be considered as an option to implement the three-level lighting protocol, depending on human occupancy and function in data centers.

6.4.2.6 Doors

Doors shall be a minimum of 1 m (3 ft) wide and 2.13 m (7 ft) high, with 2.44 m (8 ft) or higher recommended, or larger as required by AHJ, and should be sized to accommodate the largest expected equipment. The door shall have no doorsills and be hinged to open outward (code permitting), slide side-to-side, or be removable. Doors shall be fitted with locks and have either no center posts or removable center posts to facilitate access for large equipment. Exit requirements for the room shall meet the requirements of the AHJ.

6.4.2.7 Floor loading

A structural engineer shall be consulted during the design to specify the floor loading limit. The minimum distributed floor loading capacity shall be 7.2 kPA (150 lbf/ ft^2). The recommended distributed floor loading capacity is 12 kPA (250 lbf/ ft^2). Floors should be appropriately reinforced if equipment exceeding these specifications is anticipated. This requirement also applies in the case of relocation of equipment at a later time. If extensive relocation is anticipated, the entire floor should be appropriately reinforced.

The floor shall also have a minimum of 1.2 kPA (25 lbf/ ft^2) hanging capacity for supporting loads that are suspended from the bottom of the floor (for example, cable ladders suspended from the ceiling of the floor below). The recommended hanging capacity of the floor is 2.4 kPA (50 lbf/ ft^2). Refer to Telcordia specification GR-63 regarding floor loading capacity measurement and test methods.

6.4.2.8 Plywood backboards

Where wall terminations are to be used for protectors and termination hardware, adequate wall space for all anticipated protectors and termination hardware shall be covered with 19 mm (3/4 inch) plywood. The backboard shall be 1.2 m (4 ft) x 2.4 m (8 ft) sheets, mounted vertically, and with the bottom of the plywood mounted 150 mm (6 in) AFF with the best side toward the room. Plywood shall be A/C grade and finished with two coats of white fire retardant paint. Plywood shall be painted prior to installation of any equipment. Plywood shall be permanently fastened to the wall by means of wall anchors utilizing galvanized, zinc plated, or stainless-steel hardware with a flat head. Finished installation shall have flush appearance with countersunk screw heads to prevent splitting of the plywood. Drywall screws are not acceptable.

6.4.2.9 Uninterruptable power notification

Entrance doors into a room where equipment is powered by uninterruptable power systems should bear the following warning on the exterior side of door:

> “WARNING – Uninterruptible power is present in this area. Power will be present at equipment even in the event of a total building shutdown at the main service disconnect.”

The sign shall be as required by AHJ. If there are no requirements, then the sign should be permanently affixed to the door and be made mechanically to be both high visibility and high contrast with red laminate and white engraved letters that are 50 mm (2 in) minimum in height.

6.4.2.10 Signage

Signage should be developed within the security plan of the building.

6.4.2.11 Seismic considerations

Specifications for related facilities shall accommodate the applicable seismic zone requirements. Refer to Telcordia specification GR-63 for more information regarding seismic considerations.

6.4.3 Environmental design

6.4.3.1 Environment

The location of the computer room should be a $M_1I_1C_1E_1$ environment (ANSI/TIA-568.0-D). Alternatively, the computer room should be designed to create an environment compatible with $M_1I_1C_1E_1$ classifications.

6.4.3.2 Contaminants

The operating environment shall conform to environmental conditions defined as a C_1 classification in ANSI/TIA-568.0-D. Common methods to ensure meeting C_1 classification include vapor barriers, positive room pressure (where permitted by the AHJ), or absolute filtration.

6.4.3.3 HVAC

6.4.3.3.1 Operational parameters

Temperature and humidity shall be maintained to meet the requirements and should meet the recommendations for Classes A1 or A2 in ANSI/TIA-569-D.

6.4.3.3.2 Continuous operation

HVAC shall be provided on a 24 hours-per-day, 365 days-per-year basis. If the building system cannot assure continuous operation, stand-alone unit(s) shall be provided for the room.

6.4.3.3.3 Standby operation

The HVAC system should be supported by the data center standby generator system, if one is installed. If the room does not have a dedicated standby generator system, the room HVAC should be connected to the building standby generator system, if one is installed.

6.4.3.4 Radio sources

Consult with the information technology and telecommunications equipment manufacturers regarding the use of or restriction of wireless and radio systems in the room.

6.4.3.5 Batteries

If batteries are used for backup, adequate ventilation and spill containment as required shall be provided. Refer to applicable codes and standards (e.g., OSHA CFR 1926.441) for requirements.

6.4.3.6 Vibration

Refer to Telcordia specification GR-63 for more information regarding vibration testing.

6.4.4 Electrical design

6.4.4.1 Power

The room shall have duplex convenience outlets for power tools, cleaning equipment, and equipment not suitable to plug into equipment cabinet power strips. The convenience outlets should not be on the same power distribution units (PDUs) or electrical panels as the electrical circuits used for the telecommunications and computer equipment in the room. The convenience outlets shall be located on columns and along the room walls, with a minimum of one convenience outlet per wall or as required by the AHJ.

6.4.4.2 Standby power

The room electrical panels should be supported by a UPS. The UPS should be supported by a generator. If present, the generator shall be adequately sized to handle the full load including any potential harmonic load generated by the UPS and other connected load. Where no dedicated data center generator is installed, provisions should be made to connect the UPS and other data center equipment to the building generator.

6.4.4.3 Bonding and grounding (earthing)

Refer to ANSI/TIA-607-C for bonding and grounding requirements for computer rooms, entrance rooms, distributor rooms, equipment cabinets, and racks.

6.4.5 Fire protection

The fire protection systems and hand-held fire extinguishers shall comply with NFPA-75 or applicable regional code for fire extinguishers used in data centers. Sprinkler systems should be pre-action systems.

6.4.6 Water infiltration

Where risk of water ingress exists, a means of evacuating water from the space shall be provided (e.g., a floor drain, water vacuum). Additionally, at least one drain or other means for evacuating water should be provided. Any water and drain pipes that run through the room should be located away from and not directly above equipment in the room.

Any water drains that are deployed should be fitted with a means to prevent ingress of liquids or vermin into the room. Any floor drains below ground level shall be equipped with a backflow prevention device. The use of leak detectors is recommended where ever there are floor drains.

6.4.7 Access

Doors should provide access to authorized personnel only. Additionally, access to the room shall comply with the requirements of the AHJ. For additional information on monitoring computer room access, see Annex F.

6.5 Computer room requirements

6.5.1 General

The computer room is an environmentally controlled space that serves the sole purpose of supporting equipment and cabling directly related to the computer systems, data storage systems, and other telecommunications systems.

The floor layout should be consistent with equipment and facility providers' requirements, such as:

- floor loading requirements including equipment, cables, patch cords, and media (static concentrated load, static uniform floor load, dynamic rolling load);
- service clearance requirements (clearance requirements on each side of the equipment required for adequate servicing of the equipment);
- air flow requirements;
- mounting requirements;
- power requirements and DC circuit length restrictions; and
- equipment connectivity length requirements (for example, maximum channel lengths to peripherals and consoles).

6.5.2 Location

When selecting the computer room site, avoid locations that are restricted by building components that limit expansion such as elevators, building core, outside walls, or other fixed building walls. Accessibility for the delivery of large equipment to the equipment room should be provided (see ANSI/TIA-569-D).

6.5.3 Environmental design - HVAC

If the computer room does not have a dedicated HVAC system, the computer room shall be located with ready access to the main HVAC delivery system. A computer room is typically not recognized as such by the AHJ unless it has a dedicated HVAC, or utilizes the main building HVAC and has automatic dampers installed.

6.5.4 Electrical design

Separate supply circuits serving the computer room shall be provided and terminated in their own electrical panel or panels.

The power shutdown requirements for computer room equipment are mandated by the AHJ and vary by jurisdiction.

6.6 Entrance room requirements

6.6.1 General

The entrance room is a space, preferably a room, in which access provider-owned facilities interface with the data center cabling system. It typically houses telecommunications access provider equipment and is the location where access providers typically hand off circuits to the customer. This hand-off point is called the demarcation point. It is where the telecommunications access provider's responsibility for the circuit typically ends and the customer's responsibility for the circuit begins.

The entrance room will house entrance pathways, protector blocks for balanced twisted-pair and coaxial entrance cables, termination equipment for access provider cables, access provider equipment, and termination equipment for cabling to the computer room.

6.6.2 Location

The entrance room should be located to ensure that maximum circuit lengths from the access provider demarcation points to the end equipment are not exceeded. The maximum circuit lengths need to include the entire cable route, including patch cords, changes in height, and cable management routing within racks or cabinets. Annex A provides specific circuit lengths (from demarcation point to end equipment) to consider when planning entrance room locations.

NOTE: Repeaters can be used to extend circuits beyond the lengths specified in Annex A.

The entrance rooms may either be located inside or outside the computer room space. Security concerns may dictate that the entrance rooms are located outside the computer room to avoid the need for access provider technicians to access the computer room. However, in larger data centers, circuit length concerns may require that the entrance room be located in the computer room.

Cabling in the entrance rooms should use the same cable distribution (overhead or under floor) as used in the computer room; this will minimize cable lengths as it avoids a transition from overhead cable trays to under floor cable trays.

6.6.3 Quantity

Large data centers may require multiple entrance rooms to support some circuit types throughout the computer room space and/or to provide additional redundancy.

The additional entrance rooms may have their own entrance pathways for dedicated service feeds from the access providers. Alternatively, the additional entrance rooms may be subsidiaries of the primary entrance room, in which case the access provider service feeds come from the primary entrance room.

6.6.4 Entrance conduit routing under access floor

If the entrance room is located in the computer room space, the entrance conduit runs should be designed to avoid interfering with airflow, chilled water piping and other cable routing under the access floor.

6.6.5 Access provider and service provider spaces

Access provider and service provider spaces for data centers are typically located either in the entrance room or in the computer room. Refer to ANSI/TIA-569-D for information on access provider and service provider spaces.

The access provider and service provider spaces in single user data center entrance rooms typically do not require partitions because access to the data center entrance rooms is carefully controlled. Access and service providers that lease space in the computer room typically require secure access to their spaces.

6.6.6 Building entrance terminal

Outside terminals are typically used when the entrance connection is located in a closure on an outside wall of a building. Inside terminals are used when the outside cable will be connected to the inside distribution cabling system. Refer to ANSI/TIA-568.0-D, ANSI/TIA-569-D and ANSI/TIA-758-B for additional information on entrance facilities and entrance facility connections.

6.6.7 Architectural design

6.6.7.1 General

The decision of providing a room or open area should be based on security (with consideration to both access and incidental contact), the need for wall space for protectors, entrance room size, and physical location.

6.6.7.2 Size

The entrance room shall be sized to meet known and projected maximum requirements for:

- backboard and frame space for termination of access provider and campus cabling;
- access provider racks;
- customer-owned equipment to be located in the entrance room;
- demarcation racks including termination hardware for cabling to the computer room;
- pathways.

The amount of space required for the entrance room is related more closely to the number of access providers, number of circuits, and type of circuits to be terminated in the room than to the size of the data center. Meet with all access providers to determine their initial and future space requirements. See Annex B for more information regarding access provider coordination and access provider demarcation.

Space should also be provided for campus cabling. Cables containing metallic components, including optical fiber cables with metallic components, shall be terminated with protectors in the entrance room. The protectors may either be wall-mounted or frame-mounted. The space for protectors shall be located as close as practical to the point of entrance of the cables into the building. Optical fiber campus cables may be terminated in the main cross-connect instead of the entrance room if they have no metallic components (for example, cable sheath or strength member). Refer to applicable codes regarding entrance cable and entrance cable termination requirements.

6.6.7.3 Environmental design

Consider having dedicated air conditioning for the entrance room. If the entrance room has dedicated air conditioning, then air conditioning equipment should be powered by panel boards which have redundant power (e.g., generator or alternative power source). HVAC for the equipment in the entrance room should have the same degree of redundancy and backup as the HVAC and power for the computer room.

6.6.7.4 Electrical design

Consider having dedicated PDUs and UPS fed power panels for the entrance room. The quantity of electrical circuits for entrance rooms depends on the requirements of the equipment to be located in the room. The entrance rooms shall use the same electrical backup systems (UPS and generators) as that used for the computer room. The degree of redundancy for entrance room mechanical and electrical systems shall be the same as that for the computer room.

6.7 Main distribution area

6.7.1 General

The main distribution area (MDA) is the central space where the point of distribution for the structured cabling system in the data center is located. The data center shall have at least one MDA. The core routers and core switches for the data center networks are often located in or near the MDA.

In data centers that are used by multiple organizations, such as disaster recovery data centers, web hosting data centers, and colocation facilities, the MDA should be in a secure space.

6.7.2 Location

The MDA should be centrally located to avoid exceeding maximum length restrictions for the applications to be supported, including maximum cable lengths for access provider circuits served out of the entrance room.

6.7.3 Facility requirements

If the MDA is in an enclosed room, consider dedicated HVAC, PDU, and UPS fed power panels for this area.

If the MDA has dedicated air conditioning then the air conditioning equipment should be powered and controlled by panel boards which have redundant power (e.g., generator or alternative power source).

The architectural, mechanical, and electrical requirements for the MDA are the same as that for the computer room.

6.8 Intermediate distribution area

6.8.1 General

The intermediate distribution area (IDA) is the space that supports the intermediate cross-connect. It may be used to provide a second level cabling subsystem (Cabling Subsystem 2) in data centers too large to be accommodated with only Cabling Subsystem 3 (cabling from the MDA) and Cabling Subsystem 1 (cabling from HDAs to EDAs). The IDA is optional and may include active equipment.

In data centers that are used by multiple organizations, such as disaster recovery data centers, web hosting data centers, and colocation facilities, the IDA should be in a secure space.

6.8.2 Location

The IDA should be centrally located to avoid exceeding maximum length restrictions for the applications to be supported, including maximum cable lengths for access provider circuits served out of the entrance room.

6.8.3 Facility requirements

The facility requirements of an IDA are the same as that for an HDA (see 6.9.3).

6.9 Horizontal distribution area

6.9.1 General

The horizontal distribution area (HDA) is the space that supports cabling to the EDAs and optionally ZDAs. The LAN, SAN, console, and KVM switches that support the end equipment are also typically located in the HDA. The MDA may serve as a HDA for nearby equipment or for the entire computer room.

There should be a minimum of one horizontal cross-connect (HC) per floor. The HC may be in a HDA, IDA, or MDA. Additional HDAs may be required to support equipment beyond the horizontal cable length limitation.

The maximum number of connections per HDA should be adjusted based on cable tray capacity, leaving room in the cable trays for future cabling.

In data centers that are used by multiple organizations, such as disaster recovery data centers, web hosting data centers, and colocation facilities, the HDA should be in a secure space.

6.9.2 Location

The HDAs should be located to avoid exceeding maximum backbone and horizontal cabling lengths for the media types.

6.9.3 Facility requirements

If the HDA is in an enclosed room, consideration regarding a dedicated HVAC, PDUs, and UPS fed power panels for the HDA should be taken.

If the HDA has dedicated air conditioning, then they should be powered by panel boards which have redundant power (e.g., generator or alternative power source).

The architectural, mechanical, and electrical requirements for the HDA are the same as that for the computer room.

6.10 Zone distribution area

To avoid cable congestion a ZDA should be limited to 288 cables, particularly for enclosures meant to be placed overhead or under 2 ft. x 2 ft. (or 600 mm x 600 mm) access floor tiles.

Cross-connection shall not be used in the ZDA. No more than one ZDA shall be used within the same horizontal cable run.

There shall be no active equipment in the ZDA.

NOTE: Category 8 channel topologies do not contain a ZDA.

6.11 Equipment distribution areas

The EDAs are spaces allocated for end equipment, including computer systems and communications equipment.

The end equipment is typically floor standing equipment or equipment mounted in cabinets or racks.

Horizontal cables are terminated in EDAs on equipment outlets. Sufficient power receptacles and connecting hardware should be provided for each equipment cabinet and rack to minimize patch cord and power cord lengths.

6.12 Telecommunications room

In data centers, the telecommunications room (TR) is a space that supports cabling to areas outside the computer room. The TR is normally located outside the computer room but, if necessary, it can be combined with a MDA, IDA, or HDA.

The data center may support more than one telecommunications room if the areas to be served cannot be supported from a single telecommunications room.

The telecommunication rooms shall meet the specifications of ANSI/TIA-569-D.

6.13 Data center support areas

The data center support areas are spaces outside the computer room that are dedicated to supporting the data center facility. These may include but are not limited to: the operation center, support personnel offices, security rooms, electrical rooms, mechanical rooms, storage rooms, equipment staging rooms, and loading docks.

The administrative and support areas shall be cabled similarly to standard office areas, as per ANSI/TIA-568.1-D. The operation center consoles and security consoles will require larger numbers of cables than standard work area requirements. The quantity should be determined with the assistance of the operations and technical staff. The operation center may also require cabling for large wall-mounted or ceiling-mounted displays (e.g., monitors and televisions).

The electrical rooms, mechanical rooms, storage rooms, equipment staging rooms, and loading docks should have at least one wall phone each. The electrical and mechanical rooms should also have at least one data connection for access to the facility management system.

If the data center serves a critical function for an enterprise, consider terminating telecommunications cabling for the data center support areas and office space from telecommunications rooms outside the computer room.

6.14 Cabinets and racks

6.14.1 General

Cabinets and racks shall meet the specifications of ANSI/TIA-569-D.

To provide adequate space for telecommunications cabling and power strips and also factoring for the increasing depths of equipment, cabinets and racks should be 1200 mm (48 in) deep for new installations. Additionally, it is recommended to consider cabinets that are greater than 600mm (24 in) wide to accommodate management of cabling and avoid routing of cabling behind equipment exhausts where they may obstruct proper airflow.

6.14.2 "Hot" and "cold" aisles

Where alignment of cabinets is used to separate hot air and cold air, cabinets and racks shall be arranged in an alternating pattern, with fronts of cabinets/racks facing each other in a row to create “hot” and “cold” aisles. More efficient methods of hot or cold air containment may not require the orientation of cabinet/racks in a hot aisle/cold aisle configuration.

"Cold" aisles are in front of racks and cabinets. If there is an access floor, distribution of power cables or busbars can be installed under the raised floor. Alternatively, power cables or busbars can be installed overhead.

"Hot" aisles are behind racks and cabinets. If there is an access floor, cable trays for telecommunications cabling should be located under the access floor in the “hot” aisles.

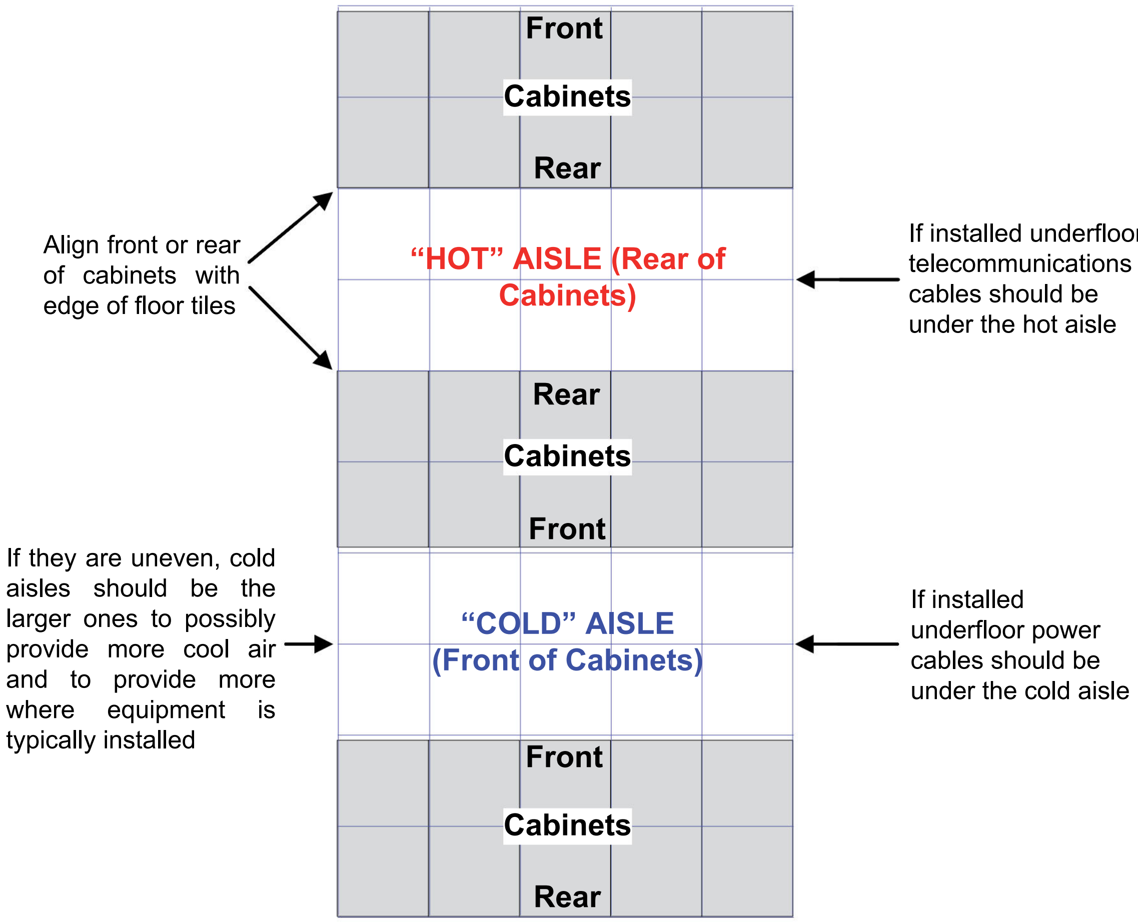


Figure 10: Example of "hot" aisles, "cold" aisles and cabinet placement

6.14.3 Placement relative to floor tile grid

When placed on access floor, cabinets and racks shall be arranged so that they permit tiles in the front and rear of the cabinets and racks to be lifted. Cabinets should be aligned with either the front or rear edge along the edge of the floor tile. Racks should be placed such that the threaded rods that secure the racks to the slab will not penetrate an access floor stringer.

6.14.4 Access floor tile cuts

Where under floor cooling is utilized, floor tile cuts should only be used to:

- accommodate cabinet vents or cooling systems, or
- route cables from under floor to above floor.

In all cases, floor tile openings should be designed to seal, as tight as possible, against the penetrations to minimize loss of under floor air pressure. Brushes, flaps, or other methods to contain static air pressure should be used.

Floor tile cuts for cabinets should be placed under the cabinets or other location where the floor tile cut will not create a tripping hazard.

Floor tile cuts for racks should be placed either: under the vertical cable managers between the racks, or under the rack (at the opening between the bottom angles). Generally, placing the floor tile cut under the vertical cable managers is preferable as it allows equipment to be located at the bottom of the rack.

The floor tile cuts shall not reduce the strength of the floor tile below the floor loading requirements specified in 6.4.2.7. One method is to draw a cross over the raised floor tile between the four corners and make a cut out where it does not touch any of the lines see Figure 11 below.

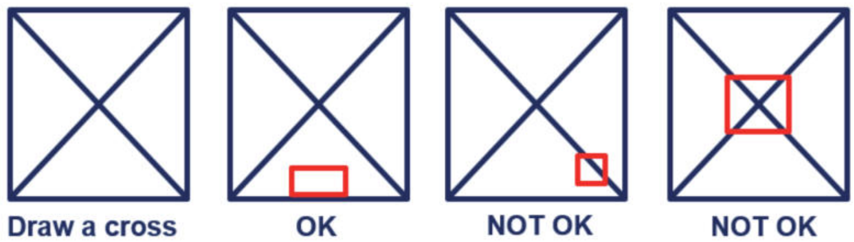


Figure 11: Tile cuts should not be where it touches any of the lines on a cross formed by the corners of the tile

6.14.5 Installation of racks on access floors

Seismic cabinets and racks shall be appropriately secured either directly to the building structure or other means (e.g., seismic platform).

Where cabinets and racks are secured directly to the building it will need to be done so in accordance with guidance provided by the AHJ or a structural engineer.

Where threaded rods are used, the top shall be covered using domed nuts or other methods.

6.14.6 Racks and cabinets in entrance room, MDAs, IDAs and HDAs

480 mm (19 in) racks are typically used for patch panels and equipment. Service providers may also install their own equipment in the entrance room in either 585 mm (23 in) racks or proprietary cabinets.

A vertical cable manager shall be installed between each pair of racks and at both ends of every row of racks. Vertical cable management shall be sized by calculating the maximum projected cable fill, including a minimum 50% additional growth factor (see ANSI/TIA-569-D). Where projected cable fill information is not available, consider deploying 250 mm (10 in) wide vertical cable managers. The cable managers should extend from the floor to the top of the racks.

Horizontal cable management, either integrated into the patch panel or as horizontal cable managers installed adjacent to each patch panel, should be provided, unless the patch panels are angled and there is adequate vertical cable management. Where used, the preferred ratio of horizontal cable management RUs to patch panels RUs is 1:1.

The vertical cable management, horizontal cable management, and slack storage should be adequate to ensure that the cables can be neatly dressed and that bend radius requirements specified in ANSI/TIA-568.0-D are met.

7 DATA CENTER CABLING SYSTEMS

7.1 General

Data center cabling generally supports multiple device types and applications in the same environment.

7.2 Choosing media

7.2.1 General

Cabling specified by this document is applicable to different application requirements within the data center environment. Depending upon the characteristics of the individual application, choices with respect to transmission media should be made. In making this choice, factors to be considered include:

- flexibility with respect to supported services;
- required useful life of cabling;
- facility/site size and occupant population;
- data throughput within the cabling system; and
- equipment vendor recommendations or specifications.

Selection of termination hardware should consider needs for proper labeling, cable routing, cable management, and ability to insert and remove cords without disrupting existing or adjacent connections.

Consider preterminated cabling to reduce installation time and improve consistency and quality of terminations.

7.2.2 Cable fire rating requirements

Cable fire-rating requirements vary by installation conditions and jurisdiction. Consult the AHJ before deciding on the type of cable to use under access floors.

> NOTE – Consider the selection of cable types (e.g., plenum-rated) and fire suppression practices that minimize damage to equipment and the facility in the event of fire

7.3 Horizontal Cabling

7.3.1 General

The horizontal cabling extends from the equipment outlet to the horizontal cross-connect.

The following partial listing of common services and systems should be considered when the horizontal cabling is designed:

- voice, modem, and facsimile telecommunications service;
- premises switching equipment;
- computer and telecommunications management connections;
- optical tap modules;
- keyboard/video/mouse (KVM) connections;
- data communications;
- wide area networks (WAN);
- local area networks (LAN);

- storage area networks (SAN); and
- other building signaling systems (building automation systems such as fire, security, power, HVAC, EMS, etc.).

In addition to satisfying today's telecommunication requirements, the horizontal cabling should be planned to reduce ongoing maintenance and relocation. It should also accommodate future equipment, applications and service changes. Consideration should be given to accommodating a diversity of user applications in order to reduce or eliminate the probability of requiring changes to the horizontal cabling as equipment needs evolve. The horizontal cabling can be accessed for reconfiguration under the access floor or overhead on cable tray systems. However, in a properly planned facility, disturbance of the horizontal cabling should only occur during the addition of new cabling.

7.3.2 Topology

Each equipment outlet in the equipment distribution area (EDA) shall be connected via horizontal cable to a horizontal cross-connect in the horizontal distribution area (HDA), intermediate distribution area (IDA), or main distribution area (MDA) as shown in Figure 12.

Horizontal cabling shall contain no more than one consolidation point in the zone distribution area (ZDA) between the horizontal cross-connect and the equipment outlet. Refer to clause 6.10 for additional information regarding ZDAs.

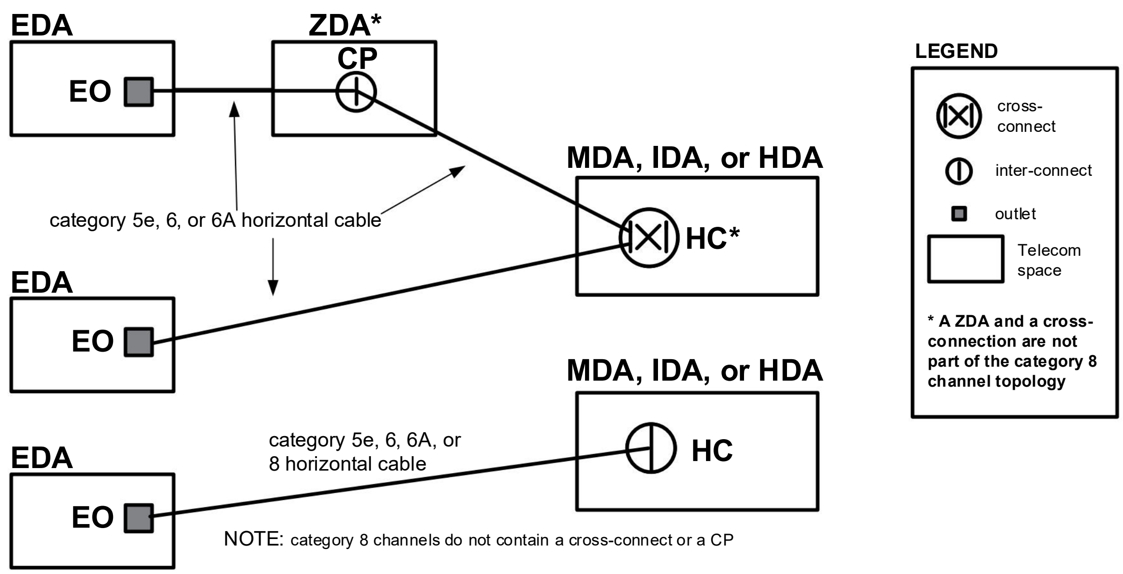


Figure 12: Typical horizontal cabling using a star topology

7.3.3 Horizontal cabling length

The horizontal cabling length shall meet the requirements of ANSI/TIA-568.0-D. The maximum horizontal cabling length for supporting 25 Gb/s and higher speed balanced twisted-pair applications shall be 30 m (98 ft) assuming a 24 m (78 ft) permanent link length and 6 m (20 ft) of cords with an insertion loss de-rating factor of 1.2.

The maximum length of horizontal coaxial cabling from the MDA shall be as specified in Annex A of this Standard for the type of applications intended to run over the coaxial cabling.

7.3.4 Direct attach cabling

The use of direct attach cabling as an alternative to structured cabling should be limited to specific use cases. Direct attach cabling between rows is not recommended. Any direct attach cabling should be routed in cable management or accessible pathways, and not interfere with fixed cabling. Where direct attach cabling is used between cabinets, each end of a cable shall be labeled with a permanent label. When direct attach cables are no longer used, the cables shall be removed.

Cable lengths for direct attach cabling between equipment in the EDA should be no greater than 7 m (23 ft) and should be between equipment in immediately (i.e. not multiple) adjacent racks or cabinets in the same row.

Direct attach cabling within distributors (MDs, IDs, HDs) and entrance spaces should be constrained within the distributor or entrance space and within a contiguous row.

7.3.5 Recognized media

Due to the wide range of services and site sizes where horizontal cabling will be used, more than one transmission medium is recognized. This Standard specifies transmission media, which shall be used individually or in combination in the horizontal cabling.

Recognized cables, related connecting hardware, jumpers, patch cords, equipment cords, and zone area cords shall meet the requirements specified in ANSI/TIA-568.2-D and ANSI/TIA-568.3-D.

The recognized media are:

- 4-pair 100-ohm balanced twisted-pair cable (ANSI/TIA-568.2-D) – category 6, category 6A, or category 8, with category 6A or higher recommended;
- 850 nm laser-optimized 50/125 um multimode fiber cable OM3, OM4, or OM5 (ANSI/TIA-568.3-D), with OM4 or OM5 recommended; Note: OM5, as used in this document, is the cable specified in ANSI/TIA-568.3-D using TIA-492AAAE multimode fibers.
- single-mode optical fiber cable (ANSI/TIA-568.3-D);
- 75-ohm 734 and 735 type coaxial cable (Telcordia Technologies GR-3175) – used for T-1, T-3, E-1, and E-3 circuits only; and
- 75-ohm broadband coaxial cables as specified in ANSI/TIA-568.4-D.

Channels constructed from recognized cables, associated connecting hardware, jumpers, patch cords, equipment cords, and zone area cords shall meet the requirements specified in ANSI/TIA-568.0-D, ANSI/TIA-568.2-D, ANSI/TIA-568.3-D and ANSI/ATIS-0600404 (DS3).

See TIA TSB-5019 that describes use cases for category 8 cabling in data centers.

7.3.6 Optical fiber connectors

In new installations, where one or two fibers are used to make a connection, the LC connector (ANSI/TIA-604-10) shall be used. Where more than two fibers are used to make a connection, the MPO connector (ANSI/TIA-604-5 or ANSI/TIA-604-18) shall be used. The connector performance shall comply with ANSI/TIA-568.3-D. See ANSI/TIA-568.3-D for polarity guidelines.

7.3.7 Coaxial cable connectors

Coaxial connectors for 75-ohm 734 and 735 type coaxial cables shall meet the requirements of ANSI/ATIS-0600404 and shall additionally meet the following specifications:

- a characteristic impedance of 75-ohm;
- a maximum insertion loss at 1 MHz to 22.5 MHz of 0.02 dB; and
- a minimum return loss at 1 MHz to 22.5 MHz of 35 dB.

Annex A permits the use of either TNC or BNC connectors, BNC connectors are recommended.

Coaxial connectors for broadband coaxial cables shall be as specified in ANSI/TIA-568.4-D – F-type male connector for series 6 or series 11 cable and 5/8-24 male connector for trunk, feeder, distribution, or braided multipurpose cable.

7.4 Backbone cabling

7.4.1 General

The function of the backbone cabling is to provide connections between the MDAs, IDAs, HDAs, telecommunications rooms, and entrance facilities in the data center cabling system. Backbone cabling consists of the backbone cables, main cross-connects, intermediate cross-connects, horizontal cross-connects, mechanical terminations, and patch cord or jumpers used for backbone-to-backbone cross-connection.

The backbone cabling is expected to serve the needs of the data center occupants for multiple planning phases, each phase spanning a timeframe from months to years. During each planning period, the backbone cabling design should accommodate growth and changes in service requirements without the installation of additional cabling. The length of the planning period is ultimately dependent on the design logistics including material procurement, transportation, installation, and specification control.

The backbone cabling shall allow network reconfiguration and future growth without disturbance of the backbone cabling. The backbone cabling should support different connectivity requirements, including both the network and physical console connectivity such as: local area networks, wide area networks, storage area networks, computer channels, equipment console connections and optical tap modules.

7.4.2 Topology

7.4.2.1 Star topology

The backbone cabling shall meet the hierarchal star topology requirements of ANSI/TIA-568.0-D. There shall be no more than two hierarchical levels of cross-connects in the backbone cabling. From the horizontal cross-connect (HC), no more than one cross-connect shall be passed through to reach the MC. Therefore, connections between any two HCs shall pass through three or fewer cross-connect facilities.

Figure 13 shows an example of a typical data center backbone cabling using a star topology wherein each horizontal cross-connect in the HDA is cabled directly to a main cross-connect in the MDA.

> NOTE: The topology required by this Standard has been selected because of its acceptance and flexibility in meeting a variety of application requirements. The limitation to two levels of cross-connects is imposed to limit signal degradation for passive systems and to simplify moves, adds and changes.

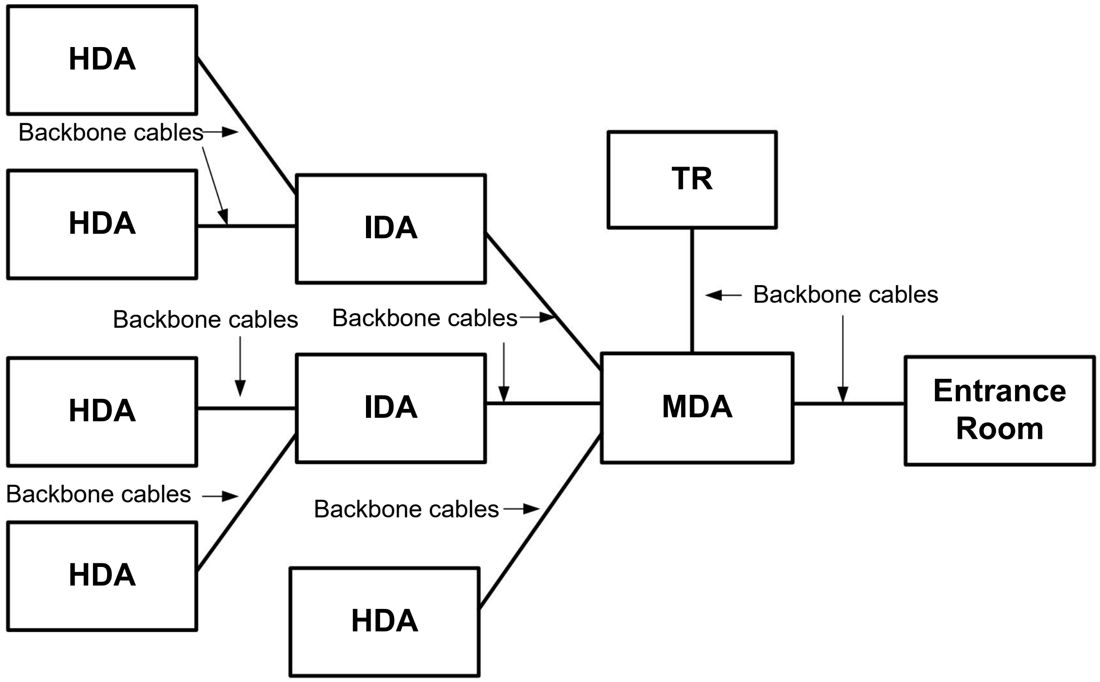


Figure 13: Typical backbone cabling using a star topology

If the horizontal cabling passes through the HDA, sufficient cable slack shall exist in the HDA to allow movement of the cables for potential future migration to a cross-connection.

Backbone cabling cross-connects may be located in telecommunications rooms, equipment rooms, MDAs, IDAs, HDAs or at entrance rooms.

7.4.2.2 Accommodation of non-star configurations

The topology in Figure 5, through the use of appropriate interconnections, electronics, or adapters in data center distribution areas, can often accommodate systems that are designed for non-star configurations such as ring, bus, or tree.

Cabling between HDAs should be permitted to provide redundancy and to avoid exceeding legacy application length restrictions.

7.4.3 Redundant cabling topologies

Redundant topologies can include a parallel hierarchy with redundant distribution areas. These topologies are in addition to the star topology specified in clauses 7.3.2 and 7.4.2. See clause 9 for additional information.

7.4.4 Recognized media

Due to the wide range of services and site sizes where backbone cabling will be used, more than one transmission medium is recognized. This Standard specifies transmission media, which shall be used individually or in combination in the backbone cabling.

The recognized media are:

- 100-ohm balanced twisted-pair cable (ANSI/TIA-568.2-D) with category 6A or higher recommended;
- 850 nm laser-optimized 50/125 um multimode fiber cable OM3, OM4, or OM5 (ANSI/TIA-568.3-D), with OM4 or OM5 recommended;
- single-mode optical fiber cable (ANSI/TIA-568.3-D);

- 75-ohm 734 and 735 type coaxial cable (Telcordia Technologies GR-3175) – used for T-1, T-3, E-1, and E-3 circuits only; and
- 75-ohm broadband coaxial cables as specified in ANSI/TIA-568.4-D.

Channels constructed from recognized cables, associated connecting hardware, jumpers, patch cords, equipment cords, and zone area cords shall meet the requirements specified in ANSI/TIA-568.0-D, ANSI/TIA-568.2-D, ANSI/TIA-568.3-D and ANSI/ATIS-0600404 (DS3).

7.4.5 Optical fiber connectors

In new installations, where one or two fibers are used to make a connection, the LC connector (ANSI/TIA-604-10) shall be used. Where more than two fibers are used to make a connection, the MPO connector (ANSI/TIA-604-5-E or ANSI/TIA-604-18) shall be used. The connector performance shall comply with ANSI/TIA-568.3-D. See ANSI/TIA-568.3-D for polarity guidelines.

7.4.6 Coaxial cable connectors

Backbone coaxial cabling connectors shall meet the horizontal coaxial cabling connector specifications in 7.3.7.

7.4.7 Backbone cabling lengths

Cabling lengths are dependent upon the application and upon the specific media chosen (see ANSI/TIA-568.0-D and the specific application standard). Annex A of this document provides guidelines for backbone lengths for data center applications.

7.5 Centralized optical fiber cabling

7.5.1 General

Centralized optical fiber cabling shall meet the requirements of ANSI/TIA-568.0-D. In a data center, centralized optical fiber cabling is designed as an alternative to the optical cross-connection located in the HDA when deploying recognized optical fiber cable in the horizontal in support of centralized electronics.

7.5.2 Implementation

The specifications of ANSI/TIA-568.0-D shall be followed. In the cases of modular or containerized data center units, centralized optical fiber may extend beyond a single building.

To ensure correct fiber polarity, centralized cabling shall be implemented as specified in ANSI/TIA-568.3-D.

7.6 Cabling transmission performance and test requirements

7.6.1 General

Transmission performance depends on cable characteristics, connecting hardware, patch cords and cross-connect wiring, the total number of connections, and the care with which they are installed and maintained. See ANSI/TIA-568.0-D for field test specifications for post-installation performance measurements of cabling designed in accordance with this Standard.

7.6.2 Additional requirements for field testing of 75-ohm coaxial cabling

Coaxial cabling shall be tested for:

- Center conductor continuity;
- Shield continuity;
- Impedance (75-ohms); and

- Insertion loss (less than the maximum specified in table 2 based on the planned applications for the cable).

Table 2: Maximum Coaxial Cable Insertion Loss

Application – Frequency	Maximum insertion loss from access provider DSX to customer equipment
CEPT-1 (E-1) - 1 MHz	3.6 dB
CEPT-3 (E-3) - 17.2 MHz	6.6 dB
T-3 - 22.4 MHz	6.9 dB

Coaxial cabling should be tested to ensure that end-to-end lengths are shorter than the lengths specified for the planned applications – see Annex A.

The cable tester should be calibrated for velocity of propagation using a sample length of the cable under test (see ANSI/TIA-1152-A). As an alternative, length may be measured or determined using jacket length markings.

Note that the maximum lengths and maximum insertion loss values provided in this Standard are end-to-end from access provider DSX panel to customer equipment including coaxial cable patch cords.

Additionally, the cabling should be visually inspected for:

- Obvious damage to cable (for example, pinched cable, cuts or abrasion that exposes the shield);
- Incorrect bend radii; and
- Loose or damaged connectors.

8 DATA CENTER CABLING PATHWAYS

8.1 General

Except where otherwise specified, data center cabling pathways shall adhere to the specifications of ANSI/TIA-569-D.

Sizing of pathways should consider quantities of cables when the data center is fully occupied and all expansion areas are built. Particular attention is required for adequate capacity of pathways at entrance rooms, main distribution areas (MDAs), intermediate distribution areas (IDAs), horizontal distribution areas (HDAs), and intersections of cabling pathways.

Usable cross-section and corresponding maximum capacity should be reduced to allow cables to exit while maintaining proper bend radius where exiting or routing past fittings such as cable dropouts.

Optical fiber cords and cables should be installed with continuous cable support and with radiused cable transition.

Where cables are installed with non-continuous cable support and without radiused cable transition, the cable should have adequate robustness to maintain required performance.

Examples of such supports are, but not limited to:

- wire basket trays without solid bottoms,
- ladders without radiused cross-members or solid bottoms,
- or hooks without radiused cable supports.

8.2 Security for data center cabling

Telecommunications cabling for data centers shall not be routed through spaces accessible by the public or by other tenants of the building unless the cables are in enclosed conduit or other secure pathways. Any maintenance holes, pull boxes, and splice boxes shall be equipped with locks. Any maintenance holes on building property or under control of the owner shall be locked and should be monitored by the security system using a camera, remote alarm or both. See ANSI/TIA-5017 for additional guidelines regarding physical network security.

Telecommunications entrance cabling for data centers should not be routed through a common equipment room (CER).

Access to pull boxes for data center cabling (entrance cabling or cabling between portions of the data center) that are located in public spaces or shared tenant spaces should be controlled. The pull boxes should also be monitored by the data center security system using a camera, remote alarm or both.

Any splice boxes for data center cabling that are located in public spaces or shared tenant spaces should be locked and monitored by the data center security system using a camera, remote alarm or both.

Entrance to utility tunnels used for telecommunications entrance rooms and other data center cabling should be locked. If the tunnels are used by multiple tenants or cannot be locked, telecommunications cabling for data centers shall be in solid metallic conduit or other secure pathway.

8.3 Routing of telecommunications cables

Separation is specified to accommodate the wide variety of equipment that may be present in a data center, but are not found in a typical office environment or telecommunications room.

8.3.1 Separation between power or lighting and balanced twisted-pair cables

The distances between power cables or lighting fixtures and balanced twisted-pair cables shall be maintained per ANSI/TIA-569-D.

It is normally possible to meet the recommended separation distances through proper design and installation practices.

In data centers that use overhead cable trays, the access headroom between the top of a tray or runway and the bottom of the tray or runway above shall be provided and maintained as specified in ANSI/TIA-569-D. This provides adequate separation if the electrical cables are shielded or if the power cable tray meets the specifications of the clause 8.3.1 and is above the telecommunications cable tray or runway.

In data centers that employ access floor systems, adequate separation of power and telecommunications cabling can be accommodated through the following measures:

- In the main aisles, allocate separate aisles for power and telecommunications cabling, if possible.
- Provide both horizontal and vertical separation of power and telecommunications cables where it is not possible to allocate separate aisles for power and telecommunications cabling in the main aisles. Provide horizontal separation by allocating different rows of tiles in the main aisles for power and telecommunications cabling, with the power and telecommunications cables as far apart from each other as possible. Additionally, provide vertical separation by placing the telecommunications cabling in cable trays or baskets as far above the power cables as possible.
- In the equipment cabinet aisles, allocate separate aisles for power and telecommunications cabling. Refer to 6.3.2.2 and 6.14.2 for additional information on cable routing and “hot” and “cold” aisles design.

8.3.2 Separation of fiber and balanced twisted-pair cabling

Fiber and balanced twisted-pair cabling in cable trays and other jointly used pathways should be separated so that it improves administration and operation. Additionally, cords and jumpers should be separated from other cabling. Physical barriers between the two types of cables are not necessary.

Where it is not practical to separate fiber and balanced twisted-pair cables, fiber cables should be on top of balanced twisted-pair cables.

8.4 Telecommunications entrance pathways

8.4.1 Entrance pathway types

Telecommunications entrance pathways for data centers should be located underground. Aerial entrance pathways for telecommunications service entrance pathways are not recommended because of their vulnerability due to physical exposure.

8.4.2 Diversity

Refer to ANSI/TIA-758-B for information regarding entrance pathway diversity.

8.4.3 Sizing

The number of entrance conduits required depends on the number of access providers that will provide service to the data center, and the number and type of circuits that the access providers will provide. The entrance pathways should also have adequate capacity to handle growth and additional access providers.

Each access provider should have at least one metric designator 103 (trade size 4) conduit at each entrance point. Additional conduits may be required for campus cabling. Conduits used for optical fiber entrance cables should have three innerducts [two metric designator 40 (trade size 1.5) and one metric designator 27 (trade size 1) or three metric designator 32 (trade size 1.25)].

Consider the use of soft-sided duct material as a substitute for innerduct, which may optimize the use of finite conduit cross-sectional area.

8.5 Access floor systems

8.5.1 General

Access floor systems should be used in data centers that support equipment that is designed to be cabled from below.

Telecommunications cabling under the access floor shall be in pathways that do not block airflow such as non-continuous supports, wire basket trays, or cable ladders.

Cables shall not be left abandoned under the access floor. Cables shall be terminated on at least one end in the MDA or a HDA, or shall be removed.

For additional information on rack and cabinet installation with access flooring systems, refer to ANSI/TIA-569-D.

8.5.2 Access floor performance requirements

Access flooring shall meet the performance requirements of ANSI/TIA-569-D.

Access floors for data centers should use a bolted stringer understructure, as they are more stable over time than stringerless systems. Pedestal adhesive should be applied under all base plates. Pedestal bases should also be bolted to the subfloor (with the exception of post-tension floors) for added stability in seismic areas. Consider installing access floor stringers in a 1.2 m (4 ft) long “basketweave” pattern where additional stability is desired (e.g., in seismically active areas).

8.5.3 Floor tile cut edging

Access floor tile cuts should have edging or grommets along all cut edges. If the edging or grommets are higher than the surface of the access floor, they shall be installed as not to interfere with placement of racks and cabinets. The edging or grommets shall not be placed where the racks and cabinets normally contact the surface of the access floor.

In the case of down-flow AC systems where the access flooring is being used as an air distribution plenum, floor tile cuts should be limited in both size and quantity to ensure proper airflow. In addition, floor tiles with cement or wood cores should have their exposed cut edges sealed in order to prevent core material from being blown into the computer room. After cuts are made to the access floor system and all equipment racks, cabinets, and frames are in place, it is recommended that the AC system be properly balanced.

8.6 Cable trays

8.6.1 General

Typical cable tray types for cable installation include telco-type cable ladders, center spine cable tray, or wire basket cable tray.

The maximum recommended depth of cable in any cable tray is 150 mm (6 in).

Cable trays may be installed in several layers to provide additional capacity. Typical installations include two or three layers of cable trays, one for power cables and one or two for telecommunications cabling. One of the cable tray layers may employ brackets on one side that hold the data center bonding infrastructure. These cable trays may be supplemented by a duct or tray system for fiber patch cables. The fiber duct or tray may be secured to the same threaded rods or pedestals used to support the cable trays.

During the design phase, the weight of fully occupied cable pathways should be calculated and coordinated with a structural engineer (if overhead) and access floor designer (if under floor).

Cable pathways should not be located where they interfere with proper operation of fire suppression systems such water distribution from sprinkler heads. Cable trays should not block airflow into or out of cabinets or ventilated tiles.

Cables shall not be left abandoned in cable trays.

The cable tray system shall be bonded and grounded per ANSI/TIA-607-C.

See ANSI/TIA-569-D for additional cable tray design considerations.

Refer to NEMA VE 2-2013 for recommendations regarding installation of cable trays.

8.6.2 Cable trays in access floor systems

To provide room for cables to exit the pathways, there shall be a minimum of 20 mm (0.75 in) from the bottom of the access floor tiles to the top of the cable tray and cabling in a cable pathway that is loaded 100% of calculated capacity.

Underfloor cable tray should not be used for direct attach cabling between rows.

Under floor systems that require periodic access or maintenance such as valves, electrical receptacles, and smoke detectors should not be located below under floor cable trays unless there is an empty row of tiles adjacent to these trays.

8.6.3 Overhead cable trays

Overhead cable tray systems may alleviate the need for access floors in data centers that do not employ floor-standing systems that are cabled from below. Overhead cable trays also minimize interference with under floor cooling.

Overhead cable trays should be suspended from the ceiling. Where building structural characteristics make overhead suspension of a cable tray impossible, the tray can be suspended from a structural grid that is supported by other means. If all racks and cabinets are of uniform height, the cable trays may be attached to the top of racks and cabinets, but this is not a recommended practice because suspended cable trays provide more flexibility for supporting cabinets and racks of various heights, and provide more flexibility for adding and removing cabinets and racks.

In aisles and other common spaces in internet data centers, co-location facilities, and other shared tenant data centers, overhead cable trays should have solid bottoms or be placed at least 2.7 m (9 ft) above the finished floor to limit accessibility or be protected through alternate means from accidental and/or intentional damage.

8.6.4 Coordination of cable tray routes

Planning of cable trays for telecommunications cabling should be coordinated with architects, mechanical engineers, and electrical engineers that are designing lighting, plumbing, air ducts, power, and fire protection systems.

Cable trays should be routed to avoid impeding airflow, sprinkler patterns, and lighting. This typically implies routing cable trays over cabinets and racks rather than above aisles between them.

Lighting fixtures and sprinkler heads should be placed between overhead cable trays, not directly above cable trays. Cable trays should be located above cabinets and racks instead of above the aisles, where lighting should be located.

9 DATA CENTER REDUNDANCY

9.1 Introduction

Data centers that are equipped with diverse telecommunications facilities may be able to continue their function under unplanned or adverse conditions that would otherwise interrupt the data center's telecommunications service. This Standard includes information on the planned availability of the data center facility infrastructure in Annex F. Figure 14 illustrates various redundant telecommunications infrastructure components that can be added to the basic infrastructure at different ratings. See Annex F for a description of data center infrastructure ratings.

The reliability of the telecommunications infrastructure can be increased by providing redundant cross-connect areas and pathways that are physically separated. It is common for data centers to have multiple access providers providing services, redundant routers, redundant core distribution and edge switches. Although this network topology provides a certain level of redundancy, the duplication in services and hardware alone does not ensure that single points of failure have been eliminated.

The proximity and response time of technicians required to perform repairs may affect reliability depending on the redundancy and architecture of the network and information technology infrastructure.

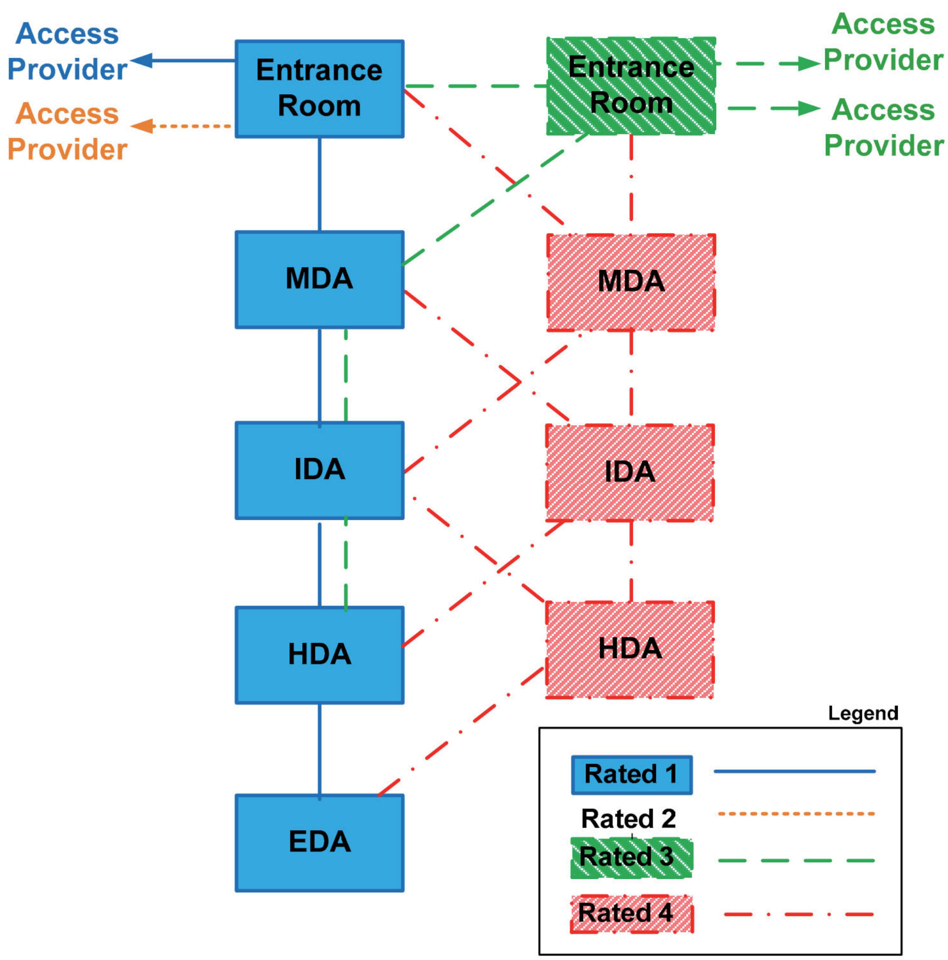


Figure 14: Telecommunications cabling pathway and space redundancy

9.2 Redundant maintenance holes and entrance pathways

Multiple entrance pathways from the property line to the entrance room(s) eliminate a single point of failure for access provider services entering the building. These pathways will include customer-owned maintenance holes where the access provider conduits do not terminate at the building wall. The maintenance holes and entrance pathways should be separated at an appropriate distance to minimize risk of one unplanned event affecting both critical paths. The recommendation is a separation of 20 m (66 ft) or more.

In data centers with two entrance rooms and two maintenance holes, it is not necessary to install conduits from each entrance room to each of the two maintenance holes. In such a configuration, each access provider is typically requested to install two entrance cables, one to the primary entrance room through the primary maintenance hole, and one to the secondary entrance room through the secondary maintenance hole. Conduits from the primary maintenance hole to the secondary entrance room and from the secondary maintenance hole to the primary maintenance hole provide flexibility, but are not required.

In data centers with two entrance rooms, conduits may be installed between the two entrance rooms to provide a direct path for access provider cabling between these two rooms (for example, to complete a SONET or SDH ring).

9.3 Redundant access provider services

Continuity of telecommunications access provider services to the data center can be ensured by using multiple access providers, multiple access provider central offices, and multiple diverse pathways from the access provider central offices to the data center.

Utilizing multiple access providers may increase service reliability in the event of an access provider-wide outage or access provider financial failure that impacts service.

Utilizing multiple access providers alone does not ensure continuity of service, because access providers often share space in central offices and share rights-of-way.

The customer should ensure that its services are provisioned from different access provider central offices and the pathways to these central offices are diversely routed. These diversely routed pathways should be separated at an appropriate distance to minimize risk of one unplanned event affecting both critical paths. The recommendation is a separation of 20 m (66 ft) or more at all points along their routes.

9.4 Redundant entrance room

Multiple entrance rooms may be installed for redundancy rather than simply to alleviate maximum circuit length restrictions. Multiple entrance rooms improve redundancy, but complicate administration.

Access providers should install circuit provisioning equipment in both entrance rooms so that circuits of all required types can be provisioned from either room. Care should be taken to distribute circuits between entrance rooms. The access provider provisioning equipment in one entrance room should not be subsidiary to the equipment in the other entrance room. The access provider equipment in each entrance room should be able to operate in the event of a failure in the other entrance room.

The two entrance rooms should be separated at an appropriate distance to minimize risk of one unplanned event affecting both rooms. The recommendation is a distance of 20 m (66 ft) or more. The two entrance rooms should be designed such that, power, fire protection and air conditioning equipment that support them are concurrently maintainable.

9.5 Redundant main distribution area

A secondary main distribution area (MDA) provides additional redundancy, but at the cost of complicating administration. Core routers and switches should be distributed between the two MDAs. Circuits should also be distributed between the two spaces.

The two MDAs should be designed such that, power, fire protection and air conditioning equipment that support the MDAs are concurrently maintainable.

9.6 Redundant backbone cabling

Redundant backbone cabling protects against an outage caused by damage to backbone cabling. Redundant backbone cabling may be provided in several ways depending on the degree of protection desired.

Backbone cabling between two spaces, for example, a HDA and a MDA, can be provided by running two cables between these spaces, preferably along different routes. If the data center has redundant MDAs or redundant IDAs, redundant backbone cabling to the HDA from each higher level distributor (IDA or MDA) is not necessary. However, the routing of cables from the HDA to the redundant IDAs or MDAs should follow different routes.

9.7 Redundant horizontal cabling

Horizontal cabling to critical systems can be diversely routed to improved redundancy. Care should be taken not to exceed maximum horizontal cable lengths when selecting paths.

Critical systems can be supported by two different HDAs as long as maximum cable length restrictions are not exceeded. The two HDAs should be in different fire protection zones for this degree of redundancy to provide maximum benefit.

10 CABLING INSTALLATION REQUIREMENTS

The installation requirements in ANSI/TIA-568.0-D, in addition to the other clauses of this Standard, shall be followed. Cabling shall comply with applicable codes and regulations.

11 CABLING PERFORMANCE REQUIREMENTS

The transmission performance requirements of ANSI/TIA-568.2-D, ANSI/TIA-568.3-D and ANSI/TIA-568.4-D shall be met.

12 CABLING FOR INTELLIGENT BUILDING SYSTEMS

Cabling for intelligent building systems that support the computer room, such as networked electrical, mechanical, and security equipment shall follow the requirements of ANSI/TIA-862-B.

13 CABLING FOR WIRELESS ACCESS POINTS

Cabling for wireless access points should follow the guidelines of TIA TSB-162-A.

14 CABLING FOR DISTRIBUTED ANTENNA SYSTEMS

Cabling for distributed antenna systems should follow the guidelines of TIA TSB-5018.

15 POWER DELIVERY OVER BALANCED TWISTED-PAIR CABLING

Power delivery over balanced twisted-pair cabling should follow the guidelines of TIA TSB-184-A.

16 GROUNDING AND BONDING

Grounding and bonding shall meet the requirements of ANSI/TIA-607-C.

17 FIRESTOPPING

Firestopping shall be in accordance with ANSI/TIA-569-D.

18 PHYSICAL SECURITY

Telecommunications infrastructure physical security shall meet the requirements of ANSI/TIA-5017.

19 ADMINISTRATION

Telecommunications administration shall meet the requirements of ANSI/TIA-606-C.

A special attention should be given to administration of the data center environment that is deploying or migrating to fiber optic cabling infrastructure based on utilizing array connectivity along with high density of ports and connections (e.g., support for leaf spine network architecture). Implementation and administration of array connectivity infrastructure requires thorough planning – need to know what you have prior to making any changes, deployment precision – consistency in creating switching fabric, as well as continuous real-time infrastructure monitoring as a risk mitigating mechanism for reducing durations of network downtime. Automated Infrastructure Management (AIM) per the ANSI/TIA-5048 standard is useful to address the challenges of complex data center environments.

The standard defines AIM as an "integrated hardware and software system that automatically detects the insertion or removal of cords, [and] documents the cabling infrastructure including connected equipment enabling management of the infrastructure and data exchange with other systems."

AIM systems enable:

- Automated documentation of the cabling infrastructure
- Proper planning and implementation of connections via electronic work orders/instructions
- End-to-end connectivity tracing capabilities that are available from management software interface as well directly at the racks/cabinets
- Continuous automated monitoring of cabling infrastructure capable of generating real time alerts
- Accurately manage and monitor connectivity and port capacity of cabling infrastructure.

ANNEX A (INFORMATIVE) CABLING DESIGN CONSIDERATIONS

This annex is informative only and is not part of this Standard.

A.1 Application cabling lengths

The maximum supportable lengths in this annex are application and media dependent.

See table 5 in ANSI/TIA-568.0-D for balanced twisted-pair applications and table 6 in ANSI/TIA-568.0-D for optical fiber applications.

A.1.1 T-1, E-1, T-3 and E-3 circuit lengths

Table 3 provides the maximum circuit lengths for T-1, T-3, E-1, and E-3 circuits with no adjustments for intermediate connections or outlets between the circuit demarcation point and the end equipment. These calculations assume that there is no customer DSX panel between the access provider demarcation point (which may be a DSX) and the end equipment. The access provider DSX panel is not counted in determining maximum circuit lengths.

Table 3: Maximum circuit lengths with no DSX panel

Circuit type	Category 3	Category 5e, 6 & 6A	734 Type Coaxial	735 Type Coaxial
T-1	159 m (520 ft)	193 m (632 ft)	-	-
CEPT-1 (E-1)	116 m (380 ft)	146 m (477 ft)	332 m (1088 ft)	148 m (487 ft)
T-3	-	-	146 m (480 ft)	75 m (246 ft)
CEPT-3 (E-3)	-	-	160 m (524 ft)	82 m (268 ft)

NOTE: The lengths shown in table 3 are for the specific applications used in data centers and may be different from the lengths supported for various applications in ANSI/TIA-568.0-D.

Repeaters can be used to extend circuits beyond the lengths specified above.

These circuit lengths should be adjusted for insertion loss losses caused by a DSX panel between the access provider demarcation point (which may be a DSX panel) and the end equipment. Table 4 provides the reduction caused by DSX panels in maximum circuit lengths for T-1, T-3, E-1, and E-3 circuits over the recognized media type.

Table 4: Reduction in circuit lengths for DSX panel

Circuit type	Category 3	Category 5e, 6 & 6A	734 Type Coaxial	735 Type Coaxial
T-1	11 m (37 ft)	14 m (45 ft)	-	-
CEPT-1 (E-1)	10 m (32 ft)	12 m (40 ft)	64 m (209 ft)	28 m (93 ft)
T-3	-	-	13 m (44 ft)	7 m (23 ft)
CEPT-3 (E-3)	-	-	15 m (50 ft)	8 m (26 ft)

Maximum circuit lengths should be adjusted for insertion loss losses caused by intermediate connections and outlets. Table 5 provides the reduction in maximum circuit lengths for T-1, T-3, E-1, and E-3 circuits over the recognized media type.

Table 5: Reduction in circuit lengths per connection or outlet

Circuit type	Category 3	Category 5e, 6, & 6A	734 Type Coaxial	735 Type Coaxial
T-1	4.0 m (13.0 ft)	1.9 m (6.4 ft)	-	-
CEPT-1 (E-1)	3.9 m (12.8 ft)	2.0 m (6.4 ft)	4.4 m (14.5 ft)	2.0 m (6.5 ft)
T-3	-	-	0.9 m (3.1 ft)	0.5 m (1.6 ft)
CEPT-3 (E-3)	-	-	1.1 m (3.5 ft)	0.5 m (1.8 ft)

In the typical data center, there are a total of three connections in the backbone cabling, three connections in the horizontal cabling and no DSX panels between the access provider demarcation point and the end equipment.

Backbone cabling:

- one connection in the entrance room;
- two connections in the main cross-connect;
- no intermediate cross-connect.

Horizontal cabling:

- two connections in the horizontal cross-connect;
- an outlet connection at the equipment distribution area.

This “typical” configuration corresponds to the typical data center with an entrance room, main distribution area (MDA), one or more horizontal distribution areas (HDAs), and no zone distribution areas (ZDAs). Maximum circuit lengths for a typical data center configuration with six connections are shown in table 6. These maximum circuit lengths include backbone cabling, horizontal cabling, and all patch cords or jumpers between the access provider demarcation point and the end equipment.

Table 6: Maximum circuit lengths for the typical data center configuration

Circuit type	Category 3	Category 5e, 6, & 6A	734 Type Coaxial	735 Type Coaxial
T-1	135 m (442 ft)	184 m (603 ft)	-	-
CEPT-1 (E-1)	92 m (303 ft)	134 m (439 ft)	305 m (1001 ft)	137 m (448 ft)
T-3	-	-	141 m (462 ft)	72 m (236 ft)
CEPT-3 (E-3)	-	-	153 m (503 ft)	78 m (257 ft)

With maximum horizontal cable lengths, maximum patch cord lengths, no customer DSX, no intermediate distribution area (IDA), and no ZDA, the maximum backbone cable lengths for T-1, E-1, T-3, or E-3 circuits are shown in table 7. This “typical” configuration assumes that the entrance room, MDA, and HDAs are separate rather than combined, and that there is no IDA. The maximum backbone cabling length is the sum of the length of cabling from the entrance room to the MDA and from the MDA to the HDA.

Table 7: Maximum backbone length for the typical data center configuration

Circuit type	Category 3	Category 5e, 6, & 6A	734 Type Coaxial	735 Type Coaxial
T-1	<1 m (<3 ft)	46 m (150 ft)	-	-
CEPT-1 (E-1)	<1 m (<3 ft)	<1 m (<3 ft)	190 m (624 ft)	29 m (95 ft)
T-3	-	-	26 m (85 ft)	0 m (0 ft)
CEPT-3 (E-3)	-	-	38 m (126 ft)	0 m (0 ft)

These calculations assume the following maximum patch cord lengths in the “typical” data center:

- 10 m (32.8 ft) for balanced twisted-pair and fiber in the entrance room, MDA, and HDA;
- 5 m (16.4 ft) for 734-type coaxial cable in the entrance room, MDA, and HDA;
- 2.5 m (8.2 ft) for 735-type coaxial cable in the entrance room, MDA, and HDA.

Due to the very short lengths permitted by category 3 balanced twisted-pair cabling and 735 type coaxial cable for T-1, T-3, E-1, and E-3 circuits, category 3 balanced twisted-pair and 735-type coaxial cables are not recommended for supporting these types of circuits.

Backbone cabling lengths can be increased by:

- limiting the locations where T-1, E-1, T-3, and E-3 circuits are provisioned (for example only in the MDA or horizontal cabling originating from the MDA);
- provisioning circuits from multiplexers or other circuit provisioning equipment located in the MDA, IDA, or HDA;
- provisioning circuits using horizontal cabling from the MDA, reducing the number of connections from six to two, and reducing the number of patch cords.

A.1.2 Baluns E-3 and T-3 circuits

Baluns permit E-3 and T-3 circuits to use twisted-pair cabling instead of 75-ohm coaxial cabling.

Lengths for E-3 and T-3 circuits over twisted-pair cabling depends on a number of factors, including the electrical characteristics of the baluns, which are beyond the scope of this Standard. However, lengths for E-3 and T-3 circuits over twisted-pair cabling using baluns will be considerably shorter than the lengths for these circuits over 734 type coaxial cabling.

Taking into account only the insertion loss of the cabling and two twisted-pair connections, the maximum lengths for E-3 and T-3 circuits with baluns over twisted-pair cabling is:

Table 8: Maximum circuit lengths over baluns NOT including insertion loss of baluns

Circuit type	Category 5e Cable & Panels	Category 6 Cable & Panels	Category 6A Cable & Panels
T-3	60.0 m (196.8 ft)	67.8 m (222.5 ft)	69.3 m (227.4 ft)
CEPT-3 (E-3)	66.2 m (217.2 ft)	74.5 m (244.2 ft)	75.9 m (249.1 ft)

These calculations assume that the baluns are attached directly to the access provider DSX panel, that there is no customer DSX panel, and that there are two twisted-pair connections. The lengths above need to be reduced by the following lengths for each decibel of insertion loss for the pair of baluns:

Table 9: Reduction in maximum circuit length for each 1 dB insertion loss for a pair of baluns

Circuit type	Category 5e Cable & Panels	Category 6 Cable & Panels	Category 6A Cable & Panels
T-3	10.2 m (33.4 ft)	11.1 m (36.6 ft)	11.4 m (37.4 ft)
CEPT-3 (E-3)	11.7 m (38.3 ft)	12.8 m (41.9 ft)	13.0 m (42.7 ft)

If the circuit is to pass through more than two connections, the circuit lengths will need to be reduced as described in table 10.

Table 10: Reduction in maximum circuit length for each additional twisted-pair connection (after the 1st two)

Circuit type	Category 5e Cable & Panel	Category 6 Cable & Panel	Category 6A Cable & Panel
T-3	1.9 m (6.3 ft)	1.1 m (3.5 ft)	1.1 m (3.5 ft)
CEPT-3 (E-3)	1.9 m (6.3 ft)	1.1 m (3.5 ft)	1.1 m (3.5 ft)

A.1.3 TIA-232 and TIA-561 console connections

The recommended maximum lengths for TIA-232-F and TIA-561/562 console connections up to 20 kb/s are:

- 23.2 m (76.2 ft) over category 3 balanced twisted-pair cable;
- 27.4 m (89.8 ft) over category 5e or higher balanced twisted-pair cable.

The recommended maximum lengths for TIA-232-F and TIA-561/562 console connections up to 64 kb/s are:

- 8.1 m (26.5 ft) over category 3 balanced twisted-pair cable;

- 9.5 m (31.2 ft) over category 5e or higher balanced twisted-pair cable.

A.2 Cross-connections

In the entrance room, MDA, IDA, and HDA, jumper and patch cord lengths used for cross-connection to backbone cabling should not exceed 20 m (66 ft).

The only exception to these length restrictions should be in the case of 75-ohm coaxial cables, for DS-3 patching, the maximum length should be 5 m (16.4 ft) for type 734 coaxial and 2.5 m (8.2 ft) for type 735 coaxial in the entrance room, main cross-connect, intermediate cross-connect, and horizontal cross-connects.

A.3 Separation of functions in the main distribution area

The MDA should have separate racks for balanced twisted-pair, coaxial cable, and optical fiber distribution unless the data center is small and the main cross-connect can fit in one or two racks. Separate patching bays for balanced twisted-pair cables, coaxial cables, and optical fiber cables simplify management and serves to minimize the size of each type of patching bay. Arrange patching bays and equipment in close proximity to minimize patch cord lengths.

A.3.1 Twisted-pair main cross-connect

The twisted-pair main cross-connect (MC) supports twisted-pair cable for a wide range of applications including low speed circuits, T-1, E-1, consoles, out-of-band management, KVM, and LANs.

Consider installing category 6A twisted-pair cabling for all balanced twisted-pair cabling from the MC to the intermediate cross-connects (ICs) and HCs, as this will provide maximum flexibility for supporting a wide variety of applications. Cabling from the E-1/T-1 demarcation area in the entrance room should be 4-pair category 5e or higher.

The type of terminations in the MC (IDC connecting hardware or patch panels) depends on the desired density and where the conversion from 1- and 2-pair access provider cabling to 4-pair computer room structured cabling occurs:

- if the conversion from 1- and 2-pair access provider cabling occurs in the entrance room, then balanced twisted-pair cable terminations in the MC are typically on patch panels. This is the recommended configuration;
- if the conversion from 1- and 2-pair access provider cabling occurs in the MC, then balanced twisted-pair cable terminations in the MC should be on IDC connecting hardware.

A.3.2 Coaxial main cross-connect

The coaxial MC supports coaxial cable for T-3 and E-3 cabling (two coaxial cables per circuit). For smaller data centers and shorter cable runs, 735-type coaxial cable may be considered. All other coaxial cabling should be 734-type coaxial cable.

Termination of coaxial cables should be on patch panels with 75-ohm BNC connectors. The BNC connectors should be female-BNC on both the front and back of the patch panels.

A.3.3 Optical fiber main cross-connect

The fiber MC supports optical fiber cable for local area networks, storage area networks, metropolitan area networks, computer channels, and SONET circuits.

Termination of fiber cables should be on optical fiber patch panels.

A.4 Separation of functions in the horizontal distribution area

HDAs should have separate cabinets or racks for balanced twisted-pair, coaxial cable, and optical fiber distribution unless the horizontal cross-connect is small and only requires one or two racks. Separate patching bays for balanced twisted-pair cables, coaxial cables, and optical fiber cables simplify management and minimize the size of each type of patching bay. Arrange patching bays and equipment in close proximity to minimize patch cord lengths.

The use of a single type of cable simplifies management and improves flexibility to support new applications. Consider installing only one type of balanced twisted-pair cable and only one type of optical fiber cable for horizontal cabling (for example all category 6 or all category 6A, and all OM4 cable or all OM3 cable).

A.5 Cabling to end equipment

Equipment cord lengths from the ZDA to floor standing systems in which patch panels cannot be installed should be limited to a maximum of 22 m (72 ft), equipment cord lengths from the ZDA to systems install in cabinets in which patch panels can be installed should be limited to a maximum of 10 m (33 ft).

If individual equipment outlets are located on the same equipment rack or cabinet as the equipment served in lieu of a ZDA, equipment cord lengths should be limited to 5 m (16 ft).

A.6 Fiber design consideration

High termination density can be achieved using multi-fiber increments and the use of MPO connectors. If cable lengths can be accurately pre-calculated, pre-terminated multi-fiber cable assemblies can reduce installation time. In these cases, the effects of additional connections should be considered to ensure overall fiber system performance. High data-rate end equipment may accommodate multi-fiber connectors directly (e.g., 40/100G Ethernet with multimode optical fiber).

A.7 Balanced twisted-pair design consideration

The patch panels should provide adequate space for labeling of each patch panel with its identifier as well as labeling each port as per ANSI/TIA-606-C requirements.

ANNEX B (INFORMATIVE) ACCESS PROVIDER INFORMATION

This annex is informative only and is not part of this Standard.

B.1 Access provider coordination

B.1.1 General

Data center designers should coordinate with local access providers to determine the access providers' requirements and to ensure that the data center requirements are provided to the access providers.

B.1.2 Information to provide to access providers

Access providers will typically require the following information for planning entrance rooms for a data center:

- address of the building;
- general information concerning other uses of the building, including other tenants;
- plans of telecommunications entrance conduits from the property line to the entrance room, including location of maintenance holes, hand holes, and pull boxes;
- assignment of conduits and innerducts (or soft-sided subducts) to the access provider;
- floor plans for the entrance facilities;
- assigned location of the access providers protectors, racks, and cabinets;
- routing of cables within entrance room (under access floor, overhead cable ladders, other);
- expected quantity and type of circuits to be provisioned by the access provider;
- date that the access provider will be able to install entrance cables and equipment in the entrance room;
- requested location and interface for demarcation of each type of circuit to be provided by the access provider;
- requested service date; and
- name, telephone number, and email address of primary customer contact and local site contact.

B.1.3 Information that the access providers should provide

The access provider should provide the following information:

- conduit requirements, including:
    - size and quantity
    - innerduct (or soft-sided subduct) size and quantity (if owner installed)
    - bend limitations
    - pull string placement
    - minimum burial depth
    - locate wire or locate ball placement
    - stub up location and specifications
- bonding requirements;
- backboard sizing;
- final grading and landscape impact;

- handhole or maintenance hole location;
- space and mounting requirements for protectors on balanced twisted-pair cables;
- quantity and dimensions of access provider racks and cabinets;
- power requirements for equipment, including receptacle types;
- service clearances; and
- installation and service schedule.

B.2 Access provider demarcation in the entrance room

B.2.1 Organization

The entrance room will have up to four separate areas for access provider demarcation:

- demarcation for low-speed balanced twisted-pair circuits, including DS-0, ISDN BRI, and telephone lines;
- demarcation for high-speed DS-1 (T-1 or fractional T-1, ISDN PRI) or CEPT-1 (E-1) balanced twisted-pair circuits;
- demarcation for circuits delivered on coaxial cable including DS-3 (T-3) and CEPT-3 (E-3); and
- demarcation for optical fiber circuits (for example, SONET OC-x, SDH STM-x, Fast Ethernet, Gigabit Ethernet, 10 Gigabit Ethernet, 40 Gigabit Ethernet, and 100 Gigabit Ethernet).

Ideally, all access providers provide demarcation for their circuits in the same location rather than in their own racks. This simplifies cross-connects and management of circuits. The centralized location for demarcation to all access providers is often called meet-me areas or meet-me racks. There should be separate meet-me or demarcation areas or racks for each type of circuit; low speed, E-1/T-1, E-3/T-3, and optical fiber. Cabling from the computer room to the entrance room should terminate in the demarcation areas.

If an access provider prefers to demarcate their services in their racks, the customer can install tie-cables from that access provider's demarcation point to the desired meet-me/demarcation area.

B.2.2 Demarcation of low-speed circuits

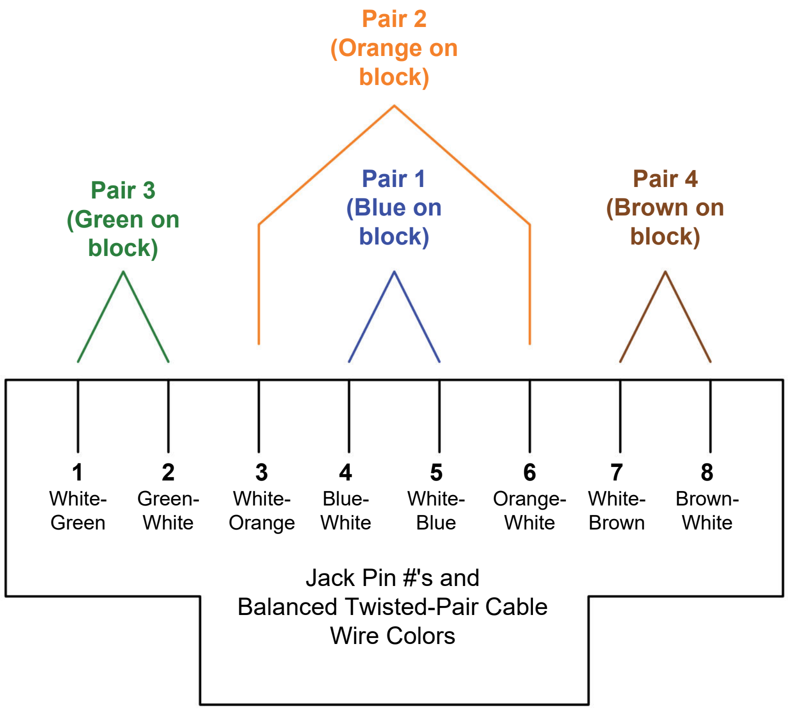
Access providers should be asked to provide demarcation of low-speed circuits on IDC connecting hardware. While service providers may prefer a specific type of IDC connecting hardware (e.g., 66 block), they may be willing to hand off circuits on another type of IDC connecting hardware upon request.

Cabling from the low-speed circuit demarcation area to the MDA should be terminated on IDC connecting hardware near the access provider IDC connecting hardware.

Circuits from access providers are terminated either in one or two pairs on the access provider IDC connecting hardware. Different circuits have different termination sequences, as illustrated in Figure 15 and Figure 16.

Each 4-pair cable should be terminated in an eight-position modular jack at the EDA. The 100 ohm balanced twisted-pair equipment outlet/connector should meet the modular interface requirements specified in IEC 60603-7. In addition, the telecommunications outlet/connector for 100 ohm balanced twisted-pair cable should meet the requirements of ANSI/TIA-568.2-D and the terminal marking and mounting requirements specified in ANSI/TIA-570-C.

Pin/pair assignments should be as shown in Figure 15 or, optionally, per Figure 16 if necessary to accommodate certain 8-pin cabling systems. The colors shown are associated with the horizontal distribution cable. These illustrations depict the front view of the equipment outlet and provide the list of the pair position for various circuit types.



(View from Front of Jack or Back of Plug)

1) **Phone Lines**:1-pair cross-connect to Pair 1(**Blue**)

2) **ISDN BRI U-Interface (U.S.)**: 1-pair cross-connect to Pair 1 (**Blue)**

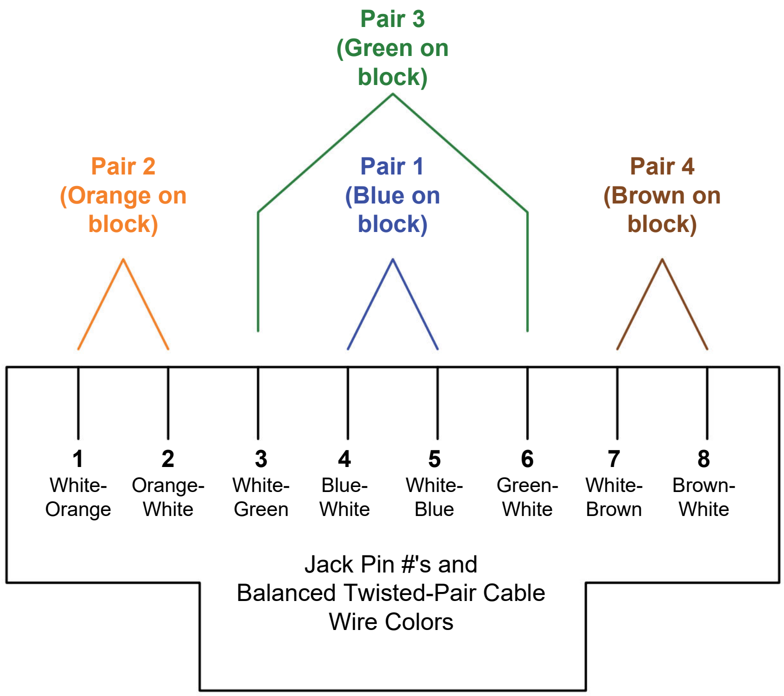
3) **ISDN BRI S/T-Intf (Intl)**: 2-pair cross-connect to Pairs 1 & 2 (**Blue** & **Orange**)

4) **56k/64k Leased Line**: 2-pair cross-connect to Pairs 3 & 4 (**Green** & **Brown**)

5) **E1/T1**: 2-pair cross-connect to Pairs 1 & 3 (**Blue** & **Green**)

6) **10Base-T/100Base-T**: 2-pair cross-connect to Pairs 2 & 3 (**Orange** & **Green**)

Figure 15: Cross-connection circuits to IDC connecting hardware cabled to modular jacks in the T568A 8-pin sequence



(View from Front of Jack or Back of Plug)

1) **Phone Lines**:1-pair cross-connect to Pair 1**(Blue**)

2) **ISDN BRI U-Interface (U.S.)**: 1-pair cross-connect to Pair 1 (**Blue)**

3) **ISDN BRI S/T-Intf (Intl)**: 2-pair cross-connect to Pairs 1 & 3 (**Blue** & **Green**)

4) **56k/64k Leased Line**: 2-pair cross-connect to Pairs 2 & 4 (**Orange** & **Brown**)

5) **E1/T1**: 2-pair cross-connect to Pairs 1 & 2 (**Blue** & **Orange**)

6) **10Base-T/100Base-T**: 2-pair cross-connect to Pairs 2 & 3 (**Orange** & **Green**)

Figure 16: Cross-connection circuits to IDC connecting hardware cabled to modular jacks in the T568B 8-pin sequence

The conversion from access provider 1-pair and 2-pair cabling to 4-pair cabling used by the data center structured cabling system can occur either in the low-speed circuit demarcation area or in the main distribution area (MDA).

The access provider and customer IDC connecting hardware can be mounted on a plywood backboard, frame, rack, or cabinet. Dual-sided frames should be used for mounting large numbers of IDC connecting hardware (3000+ pairs).

B.2.3 Demarcation of T-1 circuits

Access providers should be asked to hand-off T-1 circuits on RJ48X jacks (individual 8-position modular jacks with loop back), preferably on a DSX-1 patch panel mounted on a customer-owned rack installed in the DS-1 demarcation area. Patch panels from multiple access providers and the customer may occupy the same rack.

For example, in the United States and Canada, access providers typically use DSX-1 patch panels that fit 585 mm (23 in) racks. Thus, the DS-1 demarcation area should use one or more 585 mm (23 in) racks for access provider DS-1 patch panels. These same racks or adjacent 480 mm (19 in) racks can accommodate patch panels for cabling to the MDA. Outside the United States and Canada, access providers typically use DSX-1 panels that fit in 480 mm (19 in) racks.

The DSX-1 patch panels may require power for indicator lights. Thus, racks supporting access provider DSX-1 patch panels should, at minimum have one 20A 120V circuit and a multi-outlet power strip.

Allocate rack space for access provider and customer patch panels including growth. Access providers may require rack space for rectifiers to power DSX-1 patch panels.

Access providers can alternatively hand off DS-1 circuits on IDC connecting hardware. These IDC connecting hardware can be placed on the same frame, backboard, rack, or cabinet as the IDC connecting hardware for low-speed circuits.

A single 4-pair cable can accommodate one T1 transmit and receive pair. When multiple T1 signals are placed over multi-pair unshielded twisted-pair cable, the transmitted signals should be placed in one cable and the receive signals placed in a separate cable.

If the data center support staff has the test equipment and knowledge to troubleshoot T-1 circuits, the DS-1 demarcation area can use DSX-1 panels to terminate T-1 cabling to the MDA. These DSX-1 panels should have either modular jacks or IDC terminations at the rear.

The IDC connecting hardware, modular jack patch panels, or DSX-1 panels for cabling to the MDA can be on the same or separate racks, frames, or cabinets as the ones used for access provider DSX-1 patch panels. If they are separate, they should be adjacent to the racks assigned to the access providers.

The customer (data center owner) may decide to provide its own multiplexers (M13 or similar multiplexer) to demultiplex access provider T-3 circuits to individual T-1 circuits. T-1 circuits from a customer-provided multiplexer should not be terminated in the T-1 demarcation area.

B.2.4 Demarcation of E-3 & T-3 circuits

Access providers should be asked to hand-off E-3 or T-3 circuits on pairs of female BNC connectors, preferably on a DSX-3 patch panel on a customer-owned rack installed in the E-3/T-3 demarcation area. Patch panels from multiple access providers and the customer may occupy the same rack.

In the United States and Canada, access providers typically use DSX-3 patch panels that fit 585 mm (23 in) racks. Thus, the E-3/T-3 demarcation area should use one or more 585 mm (23 in) racks for access provider DSX-3 patch panels. These same racks or adjacent 480 mm (19 in) racks can accommodate patch panels for cabling to the MDA. Outside North America, access providers typically use DSX-3 panels that fit 480 mm (19 in) racks.

If the data center support staff has the test equipment and knowledge to troubleshoot E-3 or T-3 circuits, the E-3/T-3 demarcation area can use DSX-3 panels to terminate 734-type coaxial cabling to the MDA. These DSX-3 panels should have BNC connectors at the rear.

The DSX-3 patch panels may require power for indicator lights. Thus, racks supporting access provider DSX-3 patch panels should, at minimum have one 20A 120V circuit and a multi-outlet power strip.

Allocate rack space for access provider and customer patch panels including growth. Access providers may require rack space for rectifiers to power DSX-3 patch panels.

Cabling from the E-3/T-3 demarcation area to the MDA should be 734-type coaxial cable. Cables in the E-3/T-3 demarcation area can be terminated on a customer patch panel with 75-ohm BNC connectors, or directly on an access provider DSX-3 patch panel. Access provider DSX-3 patch panels typically have the BNC connectors on the rear of the panels. Thus, BNC patch panels for cabling to the MDA should be oriented with the front of the patch panels on the same side of the rack as the rear of the access provider DSX-3 panels.

All connectors and patch panels for E-3 and T-3 cabling should use 75-ohm BNC connectors.

B.2.5 Demarcation of optical fiber circuits

Access providers should be asked to hand-off optical fiber circuits on fiber patch panels installed on racks in the fiber demarcation area. Fiber patch panels from multiple access providers and the customer may occupy the same rack. If requested, access providers may be able to use the same connector to simplify patch cord requirements.

In the United States and Canada, access providers typically use fiber patch panels that fit 585 mm (23 in) racks, but may be able to provide patch panels that fit 480 mm (19 in) racks, if requested. In the United States, it is usually prudent to use 585 mm (23 in) racks for access provider fiber patch panels in the fiber demarcation area. These same racks or adjacent 480 mm (19 in) racks can accommodate patch panels for cabling to the MDA. Outside North America, access providers typically use fiber patch panels that fit 480 mm (19 in) racks.

The racks in the fiber demarcation area do not require power except possibly utility outlets for access provider and customer test equipment.

Cabling from the demarcation area to the MDA should be same fiber type as the access provider cabling.

ANNEX C (INFORMATIVE) COORDINATION OF EQUIPMENT PLANS WITH OTHER ENGINEERS

This annex is informative only and is not part of this Standard.

Coordinate placement of equipment and lighting in the data centers so that lighting fixtures are placed in aisles between cabinets and racks instead of directly over equipment rows.

Coordinate placement of equipment and sprinklers in the data centers so that tall cabinets or overhead cable trays do not block water dispersal from the sprinklers – the minimum clearance by Code is 460 mm (18 in). Electrical engineers will need to know placement and power requirements for equipment cabinets and racks. Coordinate routing of power cabling and receptacles with routing of telecommunications cabling and placement of equipment.

Mechanical engineers will need to know cooling requirements for equipment cabinets and racks. Coordinate placement of cable trays and telecommunications cabling to ensure that adequate airflow is maintained to all parts of the computer room. Airflow from cooling equipment should be parallel to rows of cabinets and racks. Perforated tiles should be placed in “cold” aisles, not “hot” aisles.

ANNEX D (INFORMATIVE) DATA CENTER SPACE CONSIDERATIONS

This annex is informative only and is not part of this Standard.

The data center should have an adequately sized storage room so that boxed equipment, spare air filters, spare floor tiles, spare cables, spare equipment, spare media, and spare paper can be stored outside the computer room. The data center should also have a staging area for unpacking and possibly for testing new equipment before deploying them in the computer room. It is possible to dramatically reduce the amount of airborne dust particles in the data center by having a policy of unpacking all equipment in the build/storage room.

The required size of the computer room is intimately related to the layout of the space, including not only equipment racks and/or cabinets, but also cable management and other supporting systems such as electrical power, HVAC and fire suppression. These supporting systems have space requirements that depend upon the required level of redundancy.

If the new data center replaces one or more existing data centers, one way to estimate the size of the data center is to inventory the equipment to be moved into the new data center and create a floor plan of the new data center with this equipment and expected future equipment with desired equipment adjacencies and desired clearances. The layout should assume that the cabinets and racks are efficiently filled with equipment. The floor plan should also take into account any planned technology changes that might affect the size of the equipment to be located in the new data center. The new computer room floor plan will need to include electrical and HVAC support equipment.

Often an operations center and a printer room are spaces with data center adjacency requirements, and are best designed together with the data center. The printer room should be separated from the main computer room and have a separate HVAC system because the printers generate paper and toner dust, which are detrimental to computer equipment. Storage for spare media and forms should be separated. Additionally, it is a good practice to have a separate room for tape drives, automated tape libraries, and tape libraries to reduce fuel load and because of the toxicity of smoke from burning tape.

Consider separate spaces or rooms outside the computer room for electrical, HVAC, and fire suppression system equipment, although space is not used as efficiently, security is improved because vendors and staff that service this equipment don’t need to enter the computer room.

ANNEX E (INFORMATIVE) DATA CENTER SITE SELECTION AND BUILDING DESIGN CONSIDERATIONS

This annex is informative only and is not part of this Standard.

E.1 General

Considerations that are important to the data center availability and security are provided in the charts in Annex F. Additionally, the considerations in this annex apply to higher reliability data centers.

The building should conform to all applicable national, state, and local codes.

The building and site should meet all current applicable local, state, and federal accessibility guidelines and standards.

The building should conform to the seismic standards applicable to the International Building Code Seismic Zone of the site.

The building should be free of asbestos, paint containing lead, polychlorinated biphenyl, and other environmental hazards.

Consideration should be given to zoning ordinances and environmental laws governing land use, fuel storage, sound generation, and hydrocarbon emissions that may restrict fuel storage and generator operation.

Consideration should be given to geographic location as it may impact power and cooling efficiency and availability. The difficulty in properly cooling equipment increases with altitude, thus data centers should be located below 3050 m (10,000 ft) elevation as recommended by ASHRAE.

E.2 Architectural site selection and building design considerations

The need for redundant access to the building from separate roads should be considered.

Sufficient space should be provided for all mechanical and electrical support equipment, including indoor, outdoor, and rooftop equipment. Consideration should be given to future equipment requirements.

The building should have a sufficiently large loading dock, freight elevator, and pathway to handle all anticipated deliveries of supplies and equipment.

The computer room should conform to ANSI/TIA-568.0-D E_1 classification.

The data center and all support equipment should be located above the highest expected floodwater levels. No critical electronic, mechanical or electrical equipment should be located in basement levels.

Avoid locating computer room below plumbed areas such as rest rooms, janitor closets, kitchens, laboratories, and mechanical rooms.

The computer room should have no exterior windows. If there are windows in a proposed computer room space, they should be covered for security reasons and to minimize any solar heat gain.

E.3 Electrical site selection and building design considerations

The local utility company should be able to provide adequate power to supply all initial and future power requirements for the data center. The availability and economics of redundant utility feeders possibly from separate utility substations should be considered where applicable. If the local utility cannot provide adequate power, the site should be able to support self-generation, cogeneration or distributed generation equipment. Underground utility feeders are preferable to overhead feeders to minimize exposure to lightning, trees, traffic accidents, and vandalism.

E.4 Mechanical site selection and building design considerations

A multi-tenant building will require a location designated by the landlord either on the roof or on grade for air conditioning heat rejection equipment (condensing units, cooling towers, or dry fluid coolers).

If the building has an existing fire suppression system, it should be easily modified to a pre-action sprinkler system dedicated to the data center. If the building has an existing air conditioning system serving the data center space it should be sized appropriately to ensure it can support the computer room space and support areas.

If heat rejection equipment is to be placed on-grade, then a data center site should have adequate on-grade space for the equipment and the area should be provided with unobstructed access for equipment installation and removal.

E.5 Telecommunications site selection and building design considerations

Where applicable, the building should be served by at least two diversely routed optical fiber entrance rooms. These entrance rooms should be fed from different local access provider offices. If the building is only served by a single local central office, then the service feed from the second local central office should be capable of being added without major construction or delays in obtaining permits.

Multiple telecommunications access providers should provide service or be able to provide service to the building without major construction or delays in obtaining permits.

The data center should be served by dedicated access provider equipment located in the data center space and not in shared tenant space. The access provider entrance cables should be enclosed in conduit within the building and be inaccessible to other tenants where routed through shared pathways. The building should have dedicated conduits serving the data center space for telecommunications service.

E.6 Security site selection and building design considerations

If cooling equipment, generators, fuel tanks, or access provider equipment is situated outside the customer space, then this equipment should be adequately secured.

Also, the data center owner will need access to this space 24 hours/day, 7 days/week.

Common areas should be monitored by cameras, including parking lots, loading docks, and building entrances.

The computer room should not be located directly in close proximity to a parking garage.

The site should not be located in a flood plain, near an earthquake fault, on a hill subject to slide risk, or downstream from a dam or water tower. Additionally, there should be no nearby sites that could create falling debris during an earthquake.

The site should not be in the flight path of any nearby airports.

The site should not be within 0.4 km (¼ mile) of a chemical plant, landfill, river, coastline, or dam.

The site should not be within 0.8 km (½ mile) of a military base.

The site should not be within 1.6 km (1 mile) of nuclear, munitions, or defense plants.

The site should not be located adjacent to a foreign embassy.

The site should not be located in high crime areas.

See Table 12 in Annex F for additional considerations.

E.7 Other site selection considerations

Other data center site selection criteria to consider are:

- risk of contamination;
- proximity of police stations, fire stations, and hospitals;
- general access;
- zoning ordinances;
- vibration;
- environmental issues; and
- alternate uses of the building or site after it is no longer needed as a data center (exit strategies).

ANNEX F (INFORMATIVE) DATA CENTER INFRASTRUCTURE RATING

This annex is informative only and is not part of this Standard.

F.1 General

It should be noted that human factors and operating procedures may have a greater impact on availability than the rating of the data center. This rating scheme suggests a limited number of design criteria that should be taken into consideration to improve data center reliability and security. It is not intended to be all-inclusive. Additional or alternative schemes are available in other standards and best practices.

F.1.1 Redundancy overview

Single points of failure should be eliminated to improve redundancy and reliability, both within the data center and support infrastructure as well as in the external services and utility supplies.

This Standard includes four ratings relating to various levels of resiliency of the data center facility infrastructure. The definitions of each have been expanded in this Standard.

F.1.2 Overview

This Standard includes four ratings relating to various levels of resiliency of the data center facility infrastructure. Higher ratings not only correspond to higher resiliency, but also lead to higher construction costs. In all cases, higher ratings are inclusive of lower level requirements unless otherwise specified.

A data center may have different ratings for different portions of its infrastructure. For example, a data center may be rated 3 for electrical, but 2 for mechanical. For the sake of simplicity, a data center that is rated the same for all subsystems (telecommunications, architectural and structural, electrical and mechanical) can be called out by its overall rating (e.g., a data center rated 2 would have a 2 rating in all subsystems). However where not all portions of the infrastructure are the same level, the rating should be called out specifically. For example, a data center may be rated T_2 E_3 A_1 M_2 where:

- telecommunications is rated 2 (T_2);
- electrical is rated 3 (E_3);
- architectural infrastructure is rated 1 (A_1); and
- mechanical infrastructure is rated 2 (M_2).

Although typically a data center's overall rating is based on its weakest component, there may be mitigating circumstances relative to that facilities specific risk profile, operational requirements or other factors that justify the lower rating in one or more subsystems.

Different areas within a data center may also be built and or used at different ratings dependent on operational needs. In such cases care should be given to describe these differences, for example an area of a data center that has a rating of 2 risk avoidance profile because it has T_2, E_2, A_2 M_2 services may be within a facility that is rated 3.

Care should be taken to maintain mechanical and electrical system capacity to the correct rating as the data center load increases over time. For example, a data center may be degraded from 3 or 4 to 1 or 2 as redundant capacity is utilized to support new computer and telecommunications equipment.

F.2 Redundancy

F.2.1 N - Base requirement

System meets base requirements and has no redundancy.

F.2.2 N+1 redundancy

N+1 redundancy can be implemented at the equipment level and/or path level.

Where N+1 is implemented at the equipment level within a single path, it would allow for maintenance, and potential failure, on a single piece of equipment. Path maintenance or failure could lead to an interrupt of the operations.

Where N+1 is implemented at the path level, one path is active (N) and the other path (+1) can be either on standby or active. This will allow for planned maintenance or a single fault without disrupting the operations.

F.2.3 N+x redundancy

N+x redundancy provides x additional units, modules, paths, or systems in addition to the minimum required to satisfy the base requirement. The failure or maintenance of any two single units, modules, or paths will not disrupt operations if x is 2 or higher.

F.2.4 2N or N+N redundancy

2N or N+N redundancy provides two complete units, modules, paths, or systems for every one required for a base system. Failure or maintenance of one entire unit, module, path, or system will not disrupt operations.

F.2.5 2(N+1) redundancy

2 (N+1) redundancy provides two complete (N+1) units, modules, paths, or systems. Even in the event of failure or maintenance of one unit, module, path, or system, some redundancy will be provided and operations will not be disrupted.

F.2.6 Concurrent maintainability and testing capability

The facilities should be capable of being maintained, upgraded, and tested without interruption of operations.

F.2.7 Fault tolerant

Allows for a single fault at any given time without causing disruption to the data center operations. The system should automatically detect the fault, isolate it and ensure continuous operations of the facilities.

F.2.8 Capacity and scalability

Data centers and support infrastructure should be designed to accommodate future growth with little or no disruption to services.

F.2.9 Isolation

Data centers should be (where practical) used solely for the purposes for which they were intended and should be isolated from non-essential operations.

F.2.10 Data center rating

The four data center ratings are:

<u>Rated-1 Data Center: Basic</u>

A Basic data center is susceptible to disruptions from both planned and unplanned activity on the distribution path and/or equipment (e.g., building power shutdown, maintenance/failure of equipment and/or distribution path). Operation errors or spontaneous failures of site infrastructure components may cause a data center disruption.

Rated-1 data centers have a single path for distribution of power, cooling and telecommunications. There is no requirement for component or equipment redundancy. Rated-1 data centers have little to no requirements for compartmentalization for critical facilities.

A generator is not required, but if present, is sized for UPS & mechanical systems without redundancy.

Rated-1 data centers will typically have limited physical security controls.

<u>Rated-2 Data Center: Redundant Component</u>

A Redundant Component data center is susceptible to disruptions from both planned and unplanned activity on the distribution path (e.g., building power shutdown, maintenance or failure of a distribution path). It is able to handle planned maintenance or fault on a single piece of equipment. A generator is required and sized for UPS & mechanical systems without redundancy.

Rated-2 data centers have a single path for distribution of power, cooling and telecommunications. There is a requirement for component/equipment redundancy.

Rated-2 data centers have little to no requirements for compartmentalization for critical facilities.

Rated-2 data centers will typically have basic physical security controls.

Preventative maintenance should be performed as specified by manufacturers and may require a shut down.

<u>Rated-3 Data Center: Concurrently Maintainable</u>

A Concurrently Maintainable data center is able to handle planned maintenance on any part of the distribution path or any single piece of equipment or component without causing interruption to the data center operations.

Rated-3 data centers have, at a minimum, one active (N) and one standby (+1) path for distribution of power, cooling and telecommunications. There is no requirement for component/equipment redundancy within each distribution path.

Rated-3 data centers do not require, but should be compartmentalized for electrical, mechanical and telecommunication critical facilities.

Rated-3 data centers have improved physical security controls.

<u>Rated-4 Data Center: Fault Tolerant</u>

A Fault Tolerant data center is able to handle one single fault at a time on any part of the distribution path or any single piece of equipment or component without causing interruption to the data center operations.

Rated-4 data centers have, at a minimum, dual active (2N / N+N) path for distribution of power, cooling and telecommunications. There is no requirement for component/equipment redundancy within each distribution path.

Rated-4 data centers require compartmentalization for electrical, mechanical and telecommunication critical facilities.

Rated-4 data centers have strong physical security controls.

F.3 Telecommunications

Figure 14 in clause 9 illustrates data center telecommunications cabling pathway infrastructure redundancy.

F.3.1 I Data Center: Basic (telecommunications)

In addition to the requirements and guidelines in this Standard, a Basic facility will have one customer owned maintenance hole and entrance pathway to the facility. The access provider services will be terminated within one entrance room. The telecommunications infrastructure will be distributed from the entrance room to the main distribution and horizontal distribution areas (HDAs) throughout the data center via a single pathway. Although logical redundancy may be built into the network topology, there is no requirement for physical redundancy or diversification provided within such a facility.

Some potential single points of failure of such a facility are:

- access provider outage, central office outage, or disruption along an access provider right-of-way;
- access provider equipment maintenance or failure;
- router or switch maintenance or failure, if they are not redundant;
- any catastrophic event or maintenance within the entrance room, main distribution area (MDA), or maintenance hole may disrupt all telecommunications services to the data center; and
- damage or disconnection of backbone or horizontal cabling.

F.3.2 II Data Center: Redundant Component (telecommunications)

The telecommunications infrastructure should meet the requirements of section F.3.1.

Critical telecommunications equipment, access provider provisioning equipment, production routers, production LAN switches, and production SAN switches, should have redundant components (power supplies, processors).

Intra-data center LAN and SAN backbone cabling from switches to backbone switches should have redundant fiber or wire pairs within the overall star configuration. The redundant connections may be in the same or different cable sheaths.

Logical configurations are possible and may be in a ring or mesh topology superimposed onto the physical star configuration.

Such a facility addresses vulnerability of telecommunications services entering the building.

Such a facility should have two customer owned maintenance holes and entrance pathways to the facility. The two redundant entrance pathways will be terminated within one entrance room.

All patch cords and jumpers should be labeled at both ends of the cable with the name of the connection at both ends of the cable.

Some potential single points of failure of such a facility are:

- access provider outage, central office outage, or disruption along an access provider right-of-way;
- access provider equipment located in the entrance room connected to same electrical distribution and supported by single HVAC components or systems;
- redundant LAN or SAN switches connected to same electrical circuit or supported by single HVAC components or systems;
- any catastrophic event or maintenance within the entrance room or MDA may disrupt all telecommunications services to the data center; and
- any catastrophic event within a distributor may disrupt all services to the area it serves.

F.3.3 III Data Center: Concurrently Maintainable (telecommunications)

The telecommunications infrastructure should meet the requirements of section F.3.2.

The data center should be served by at least two access providers. Service should be provided from at least two different access provider central offices or points-of-presences. Access provider cabling (including maintenance holes) from their central offices or points-of-presences should be separated as much as practical and by at least 20 m (66 ft) along their entire routes to be considered diversely routed.

The data center should have two entrance rooms preferably at opposite ends of the data center, but a minimum of 20 m (66 ft) physical separation between the two rooms. Do not share access provider provisioning equipment, fire protection zones, power distribution units, and air conditioning equipment between the two entrance rooms. The access provider provisioning equipment in each entrance room should be able to continue operating if the equipment in the other entrance room is undergoing planned maintenance. Consideration should be given, although not required, to have an automated failover so that catastrophic failures of equipment in one room does not cause a disruption to the data center operations.

The data center should have redundant backbone pathways between the entrance rooms, MDA, IDAs, and HDAs.

Intra-data center LAN and SAN backbone cabling from switches to backbone switches should have redundant fiber or wire pairs within the overall star configuration. The redundant connections should be in diversely routed cables.

All cabling, cross-connects and patch cords should be documented using software systems or automated infrastructure management systems as described in the ANSI/TIA-606-C.

Some potential single points of failure of such a facility are:

- any catastrophic event within the MDA may disrupt all telecommunications services to the data center; and
- any catastrophic event within a HDA may disrupt all services to the area it serves.

F.3.4 IV Data Center: Fault Tolerant (telecommunications)

The telecommunications infrastructure should meet the requirements of section F.3.3.

Data center backbone cabling and distributor locations should be redundant. Cabling between two spaces should follow physically separate routes, with common paths only inside the two end spaces.

There should be automatic backup for all critical telecommunications equipment, access provider provisioning equipment, core layer production routers and core layer production LAN/SAN switches. Sessions/connections should switch automatically to the backup equipment.

The data center should have redundant MDAs preferably at opposite ends of the data center, but a minimum of 20 m (66 ft) physical separation between the two spaces. Do not share fire protection zones, power distribution units, and air conditioning equipment between the redundant MDAs. The redundant MDA is optional, if the computer room is a single continuous space, as there is probably little to be gained by implementing two MDAs in this case.

The two MDAs should have separate pathways to each entrance room. There should also be a telecommunications cabling pathway between the MDAs.

The redundant routers and switches should be distributed between redundant distribution spaces (e.g., redundant MDAs, redundant pair of IDAs, or redundant pair of HDAs, or redundant pair of entrance rooms).

Each HDA should be provided with connectivity to two different IDAs or MDAs. Similarly, each IDA should be provided with connectivity to both MDAs.

Critical systems should have horizontal cabling to two HDAs.

Some potential single points of failure of such a facility are at:

- the MDA (if the secondary distribution area is not implemented); and
- the HDA and horizontal cabling (if redundant horizontal cabling is not installed).

F.4 Architectural and structural

F.4.1 General

The building structural system should be either steel or concrete. At a minimum, the building frame should be designed to withstand wind loads in accordance with the applicable building codes for the location under consideration and in accordance with provisions for structures designated as essential facilities (for example, Building Classification III from the International Building Code).

F.4.2 I Data Center: Basic (architectural)

Architecturally, a Basic data center is a data center with no requirements for protection against physical events, intentional or accidental, natural or man-made, which could cause the data center to fail.

F.4.3 II Data Center: Redundant Component (architectural)

Redundant component data centers have minimal protections against some physical events, intentional or accidental, natural or man-made, which could cause the data center to fail. They have minimal security measures in place such as perimeter security and entry control of the facilities areas and computer room.

F.4.4 III Data Center: Concurrently Maintainable (architectural)

Concurrently Maintainable data centers have appropriate protections against some physical events, intentional or accidental, natural or man-made, which could cause the data center to fail. It has adequate security and monitoring for critical/restricted areas. It should preferably have compartmentalization of at least the electrical, mechanical, and telecommunication spaces.

F.4.5 IV Data Center: Fault Tolerant (architectural)

A Fault Tolerant data center has considered all potential physical events that could cause the data center to fail. Such a data center has provided specific and in some cases redundant protections against such events. Such data centers consider the potential problems with natural disasters such as seismic events, floods, fire, hurricanes, and storms, as well as potential problems with terrorism and disgruntled employees. These data centers have control over all aspects of their facility. It has full security and monitoring for critical/restricted areas. It has compartmentalization across all electrical, mechanical and telecommunication spaces.

F.5 Electrical

F.5.1 I Data Center: Basic (electrical)

A Basic facility provides the minimum level of power distribution to meet the electrical load requirements. It has no redundancy. The electrical systems are single path and have single components whereby a failure of or maintenance to a component or part of the distribution path will cause partial or total interruption of operations.

Generators may be installed as single units or paralleled for capacity, but there is no redundancy requirement. One or more automatic transfer switches are typically used to sense loss of normal power, initiation of generator start and transfer of loads to the generator system. Provisions to connect portable load banks should be provided for generator and UPS testing.

The uninterruptible power supply system can be installed as a single unit or paralleled for capacity. Static, rotary or hybrid UPS technologies can be utilized, with VI (Voltage Independent) or VFI (Voltage and Frequency Independent) designs. Compatibility of the UPS system with the generator system is required. The UPS system should have a maintenance bypass feature to allow continuous operation during maintenance of the UPS system.

Separate transformers and panel boards are acceptable for the distribution of power to the critical electronic loads in these data centers. The transformers should be designed to handle the non-linear load that they are intended to feed. Harmonic canceling transformers can also be used in lieu of K-rated transformers.

Power distribution units (PDU) or discrete transformers and panel boards may be used to distribute power to the critical electronic loads. Any code compliant wiring method may be utilized. Grounding system should conform to minimum code requirements.

Monitoring of electrical and mechanical systems is optional.

F.5.2 II Data Center: Redundant Component (electrical)

Redundant Component installations should meet all requirements of section F.5.1. In addition, such a facility provides for N+1 redundant UPS modules. A generator system sized to handle all data center loads is required, although redundant generator sets are not required. No redundancy is required in the utility service entrance or power distribution system.

Provisions to connect portable load banks should be provided for generator and UPS testing.

Power distribution is based on a single path. Although not required, it is recommended to have two PDU’s at common output of the UPS cluster allowing for the provisioning of an A and B feed to each ICT equipment. Usage of color-coding is recommended.

A circuit should not serve more than one rack/cabinet to prevent a circuit fault from affecting more than one rack/cabinet. To provide redundancy, racks and cabinets should each have two dedicated electrical circuits fed from two different power distribution units (PDUs) or electrical panels. Each receptacle should be identified with the PDU and circuit number, which serves it. Redundant feeder to mechanical system distribution board is recommended but not required.

Consider redundancy and isolation in the fuel storage system to ensure that fuel system contamination or a mechanical fuel system failure does not affect the entire generator system.

F.5.3 III Data Center: Concurrently Maintainable (electrical)

There should be two utility entrance feeds which are allowed to come from a single substation. Where no multiple utility feeds are available, self-generation is acceptable. Generators should be present in an N+1 configuration which is allowed to be shared between each of the utility entrances.

Dual path distribution should be from utility entrance all the way to the ICT equipment. All equipment should be dual corded. Where this is not available an STS should be installed.

At a minimum one feed should be active with N capacity and the other feed (+1) is allowed to be on standby to allow for planned maintenance activities. It is highly recommended to have both feeds active so that an unplanned event on the active feed could facilitate an automatic switch over to the other feed.

Equipment for each path should be compartmentalized so that maintenance on any electrical room for one path will not lead to a disruption to the other path.

A central power and environmental monitoring and control system (PEMCS) should be provided to monitor all major electrical equipment such as main switchgears, generator systems, UPS systems, automatic static transfer switches (ASTS), power distribution units, automatic transfer switches, motor control centers, transient voltage surge suppression systems, and mechanical systems. A separate programmable logic control system should be provided, programmed to manage the mechanical system, optimize efficiency, cycle usage of equipment and indicate alarm condition.

F.5.4 IV Data Center: Fault Tolerant (electrical)

There should be two utility entrance feeds which should come from different substations. Where no multiple utility feeds are available, self-generation is acceptable. Generators shall be present in at least an N configuration for each feed and shall not be shared between each of the utility entrances.

Dual path distribution should be from utility entrance all the way to the ICT equipment. All equipment shall be dual corded. Where this is not available an STS should be installed.

All feeds shall be active with N capacity. Any single planned or unplanned event on any feed must facilitate an automatic switch over to the other feed.

Equipment for each path shall be compartmentalized so that maintenance or a catastrophic failure on any electrical room for one path will not lead to a disruption to the other path.

Battery monitoring should be at least at the string level performed by the UPS. Preference is for a battery monitoring system capable of individually monitoring the impedance or resistance of each cell and temperature of each battery jar and alarming on impending battery failure.

F.6 Mechanical systems

F.6.1 I Data Center: Basic (mechanical)

The HVAC system of a Basic facility includes single or multiple air conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions with no redundant units. If these air conditioning units are served by a water-side heat rejection system, such as a chilled water or condenser water system, the components of these systems are likewise sized to maintain design conditions, with no redundant units. The piping system or systems are single path, whereby a failure of or maintenance to a section of pipe will cause partial or total interruption of the air conditioning system.

Electrical distribution to the air conditioning equipment is single path. Any failure or maintenance may cause disruption of cooling.

If a generator is provided, all air conditioning equipment should be powered by the standby generator system.

The required cooling capacity should be calculated based on the kW (not kVA) supply available from the UPS system.

F.6.2 II Data Center: Redundant Component (mechanical)

The HVAC system of a Redundant Component facility includes multiple air conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions, with one redundant unit (N+1). If these air conditioning units are served by a water system, the components of these systems are likewise sized to maintain design conditions, with one redundant unit(s). The piping system or systems are single path, whereby a failure of or maintenance to a section of pipe will cause partial or total interruption of the air conditioning system.

Air conditioning systems should be designed for continuous operation 7 days/24 hours/365 days/year, and incorporate a minimum of N+1 redundancy in the computer room air conditioning (CRAC) units.

The computer room air conditioners (CRAC) system should be provided with N+1 redundancy, with a minimum of one redundant unit for every five to eight required units.

Air conditioning equipment should have backup power from the standby generator system.

Although redundancy is not required for the power distribution to the air conditioning equipment, if redundancy is provided, it is advisable to distribute power connections of the air conditioners over multiple electrical boards. Alternatively, a transfer switch could be used to provide the equipment with two power feeds.

Air supply to the data center should be coordinated with the types and layouts of the cabinets and racks to be installed. The air handling plant should have sufficient capacity to support the total projected heat load from equipment, lighting, the environment, etc., and maintain constant relative humidity levels within the data center.

F.6.3 III Data Center: Concurrently Maintainable (mechanical)

The HVAC system of a Concurrently Maintainable facility includes multiple air conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions, with sufficient redundant units to allow maintenance to any equipment or path. If these air conditioning units are served by a water-side heat rejection system, such as a chilled water or condenser water system, the components of these systems are likewise sized to maintain design conditions, with one electrical switchboard removed from service. This level of redundancy can be obtained by either furnishing two sources of power to each air conditioning unit, or dividing the air conditioning equipment among multiple sources of power. The piping system or systems shall be designed such that maintenance to a section of pipe will not cause interruption of the air conditioning system. Alternatively, other cooling back measures could enable maintenance to piping such as dual-coil (condenser water supply/direct expansion) air conditioning systems.

Redundant computer room air conditioning (CRAC) units should be served from separate panels to provide electrical redundancy. All computer room air conditioners (CRAC) units should be backed up by generator power.

Concurrently maintainable refrigeration equipment should be dedicated to the data center. Sufficient redundancy should be provided to enable isolation of any item of equipment as required for essential maintenance without affecting the services being provided with cooling.

F.6.4 IV Data Center: Fault Tolerant (mechanical)

The HVAC system of a Fault Tolerant facility includes multiple air conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions, with sufficient redundant units to allow failure of or service to one electrical switchboard. If these air conditioning units are served by a water-side heat rejection system, such as a chilled water or condenser water system, the components of these systems are likewise sized to maintain design conditions, with one electrical switchboard removed from service. his level of redundancy can be obtained by either furnishing two sources of power to each air conditioning unit, or dividing the air conditioning equipment among multiple sources of power. The piping system or systems should be designed such that maintenance or failure to a section of pipe will not cause interruption of the air conditioning system. Alternatively, other cooling back measures could enable maintenance to piping such as dual-coil (condenser water supply/direct expansion) air conditioning systems.

All computer room air conditioners (CRAC) units should be backed up by generator power.

Fault tolerant refrigeration equipment should be dedicated to the data center. Sufficient redundancy should be provided to enable isolation of any item of equipment as required for essential maintenance or failure without affecting the services being provided with cooling.

Table 11: Reference guide (telecommunications)

	1 (T_1)	2 (T_2)	3 (T_3)	4 (T_4)
TELECOMMUNICATIONS				
General				
Cabling, racks, cabinets, & pathways compliant with relevant TIA specifications	Yes	Yes	Yes	Yes
Diversely routed access provider entrances and maintenance holes with minimum 20 m separation	Not required	Yes	Yes	Yes
Redundant access provider services – multiple access providers, central offices, access provider right-of-ways	Not required	Not required	Yes	Yes
Redundant entrance room	Not required	Not required	Yes	Yes
Redundant main distribution area	Not required	Not required	Not required	Yes
Redundant intermediate distribution areas (if present)	Not required	Not required	Not required	Yes
Redundant backbone cabling and pathways	Not required	Not required	Yes	Yes
Redundant horizontal cabling and pathways	Not required	Not required	Not required	Yes
Routers and switches have redundant power supplies, processors	Not required	Yes	Yes	Yes
Redundant routers and switches with redundant uplinks	Not required	Not required	Yes	Yes
Patch panels, outlets, and cabling to be labeled per ANSI/TIA-606-C. Cabinets and racks to be labeled on front and rear.	Yes	Yes	Yes	Yes
Patch cords and jumpers to be labeled on both ends with the name of the connection at both ends of the cable	Not required	Yes	Yes	Yes
Patch panel and patch cable documentation compliant with ANSI/TIA-606-C.	Not required	Not required	Yes	Yes

Table 12: Reference guide (architectural)

	1 (A_1)	2 (A_2)	3 (A_3)	4 (A_4)
ARCHITECTURAL				
Site selection				
Proximity to flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map	Not required	Not required	Not within 100-year flood hazard area	Greater than 91 m (300 ft) from 100-year flood hazard area
Proximity to coastal or navigable inland waterways	Not required	Not required	Greater than 91 m (300 ft)	Greater than 0.8 km (1/2 mile)
Proximity to major highway traffic arteries and main rail lines	Not required	Not required	Greater than 91 m (300 ft)	Greater than 0.8 km (1/2 mile)
Proximity to major airports	Not required	Not required	Greater than 1.6 km (1 mile)	Greater than 8 km / 5 miles
Parking				
Separate visitor and employee parking areas	Not required	Not required	Yes (physically separated by fence or wall with separate entries)	Yes (physically separated by fence or wall with separate entries)
Separate from loading docks	Not required	Not required	Yes (physically separated with separate entries)	Yes (physically separated by fence or wall with separate entries)
Proximity of visitor parking to data center perimeter building walls	Not required	Not required	Physical barriers to prevent vehicles from driving to wall of data center facilities areas or computer room	Physical barriers to prevent vehicles from driving to wall of data center facilities areas or computer room
ulti-tenant non-data center occupant within building	No restriction	Allowed only if occupancies are non-hazardous	Allowed if all tenants are data centers or telecommunications companies	Allowed if all tenants are data centers or telecommunications companies
Building construction				
Type of construction (IBC 2015) or equivalent locally adopted building code	No restriction	No restriction	Type IIA, IIIA, or VA	Type IA or 1B
Fire resistive requirements				
Exterior bearing walls	Code allowable	Code allowable	1 Hour minimum	4 Hours minimum
Interior bearing walls	Code allowable	Code allowable	1 Hour minimum	2 Hour minimum
Exterior nonbearing walls	Code allowable	Code allowable	1 Hour minimum	4 Hours minimum
Structural frame	Code allowable	Code allowable	1 Hour minimum	2 Hour minimum
Interior non-computer room partition walls	Code allowable	Code allowable	1 Hour minimum	1 Hour minimum
Interior computer room partition walls	Code allowable	Code allowable	1 Hour minimum	2 Hour minimum
Shaft enclosures	Code allowable	Code allowable	1 Hour minimum	2 Hour minimum
Floors and floor-ceilings	Code allowable	Code allowable	1 Hour minimum	2 Hour minimum
Roofs and roof-ceilings	Code allowable	Code allowable	1 Hour minimum	2 Hour minimum
Meet NFPA 75 or alternatively the data center fire protection standard applicable for the location	Not required	Yes	Yes	Yes

	1 (A_1)	2 (A_2)	3 (A_3)	4 (A_4)
Miscellaneous Building components				
Vapor barriers for walls, floors, and ceiling of computer room	Not required	Yes for walls, Not required for ceiling	Yes	Yes
Building entrances with security checkpoints	Not required	Not required	Yes (primary building entrance manned)	Yes (primary building entrance manned)
Access floor panel construction (when provided)	No requirement	No requirement	Computer grade with appropriate floor loading capability	Computer grade with appropriate floor loading capability
Understructure (when access floor is provided)	No requirement	No requirement	bolted stringer	bolted stringer
Roofing				
Class	No restrictions	Class A	Class A	Class A
Type	No restrictions	No restrictions	Non-redundant with non-combustible deck (no mechanically attached systems)	Double redundant with concrete deck (no mechanically attached systems)
Roof Slope	Minimum Code requirements	Minimum Code requirements	1:48 (1/4 in per foot) minimum	1:24 (1/2 in per foot) minimum
Doors and windows				
Fire rating	Minimum Code requirements	Minimum Code requirements	Minimum Code requirements (not less than 3/4 hour at computer room)	Minimum Code requirements (not less than 1 1/2 hour at computer room)
Windows on perimeter of computer room	Allowed with minimum Code required fire rating	Allowed with minimum Code required fire rating	Interior windows allowed with minimum 1-hour fire rating, no exterior windows allowed	Interior windows with minimum 2-hour fire rating, no exterior windows allowed
Entry Lobby				
Physically separate from other areas of data center	Not required	Yes	Yes	Yes
Fire separation from other areas of data center	Minimum Code requirements	Minimum Code requirements	Minimum Code requirements (not less than 1 hour)	Minimum Code requirements (not less than 2 hour)
Security counter	Not required	Not required	Yes	Yes (physically separated from other areas of the data center)
Single person interlock, portal or other hardware designed to prevent piggybacking or pass back	Not required	Not required	Yes	Yes

	1 (A_1)	2 (A_2)	3 (A_3)	4 (A_4)
Administrative offices				
Physically separate from other areas of data center	Not required	Yes	Yes	Yes
Fire separation from other areas of data center	Minimum Code requirements	Minimum Code requirements	Minimum Code requirements (not less than 1 hour)	Minimum Code requirements (not less than 2 hour)
Security office				
Physically separate from other areas of data center	Not required	Not required	Yes	Yes
Fire separation from other areas of data center	Minimum Code requirements	Minimum Code requirements	Minimum Code requirements (not less than 1 hour)	Minimum Code requirements (not less than 2 hour)
180-degree peepholes or CCTV on security equipment and monitoring rooms	Not required	Yes	Yes	Yes
Dedicated and hardened security equipment and monitoring rooms	Not required	Yes	Yes, solid core, reinforced or steel doors	Yes, solid core, reinforced or steel doors
Operations Center				
Operations Center physically separate from other areas of data center	Not required	Not required	Yes	Yes
Fire separation from other non-computer room areas of data center	Not required	Not required	1 hour	2 hour
Restrooms and break room areas				
Proximity to computer room and support areas	No requirement	No requirement	If immediately adjacent, provided with leak prevention barrier	Not immediately adjacent and provided with leak prevention barrier
Fire separation from computer room and support areas	Minimum Code requirements	Minimum Code requirements	Minimum Code requirements (not less than 1 hour)	Minimum Code requirements (not less than 2 hour)
UPS and Battery Rooms				
Aisle widths for maintenance, repair, or equipment removal	No requirement	Minimum Code requirements (not less than 1.2 m (4 ft) clear)	Minimum Code requirements (not less than 1.2 m (4 ft) clear)	Minimum Code requirements (not less than 1.2 m (4 ft) clear)
Fire separation from computer room and other areas of data center	Minimum Code requirements	Minimum Code requirements	Minimum Code requirements (not less than 1 hour)	Minimum Code requirements (not less than 2 hour)
Required Exit Corridors				
Fire separation from computer room and support areas	Minimum Code requirements	Minimum Code requirements	Minimum Code requirements (not less than 1 hour)	Minimum Code requirements (not less than 2 hour)
Width	Minimum Code requirements	Minimum Code requirements	Minimum Code requirements of 1.2 m (4 ft), whichever is greater	Minimum Code requirements of 1.2 m (4 ft), whichever is greater

	1 (A_1)	2 (A_2)	3 (A_3)	4 (A_4)
Shipping and receiving area				
Shipping and receiving area physically separate from other areas of data center	No shipping and receiving area provided	Not required	Yes	Yes
Fire separation from other areas of data center	Minimum Code requirements if shipping and receiving area present	Minimum Code requirements	1 hour	2 hour
Number of loading docks	No requirement	minimum of 1	minimum of 1	minimum of 1 with an alternate delivery route for small/rack mountable equipment
Generator and fuel storage areas				
Proximity to computer room and support areas	No requirement	No requirement	As per code requirements. If within data center building, provided with a minimum of 2 hr fire rated wall. If outside of data center building appropriate security measures shall be provided	As per code requirements. If within data center building, provided with a minimum of 2 hr fire rated wall. If outside of data center building appropriate security measures shall be provided
Proximity to publicly accessible areas	No requirement	No requirement	Appropriate distance or protective measures	Appropriate distance or protective measures
Security				
System CPU UPS capacity	No requirement	Building UPS	Building UPS	Building UPS or local battery backup (8 hour min)
Data Gathering Panels (Field Panels) UPS Capacity	No requirement	Building UPS or local battery backup (4 hour min)	Building UPS or local battery backup (8 hour min)	Building UPS or local battery backup (24 hour min)
Field Device UPS Capacity	No requirement	Building UPS or local battery backup (4 hour min)	Building UPS or local battery backup (8 hour min)	Building UPS or local battery backup (24 hour min)
Physical security staffing	No requirement	During scheduled operation (typically 5 days a week during normal business hours)	7 days a week, 24 hours a day	7 days a week, 24 hours a day with sufficient spare personnel to allow for physical inspections, walk alongs, supervisions etc

	1 (A_1)	2 (A_2)	3 (A_3)	4 (A_4)
Security Access Control/Monitoring at:				
Perimeter and restricted areas	industrial grade lock	intrusion detection with intrusion detection with door/window open alarm	card access or biometric with intrusion detection with door/window open alarm	card access or biometric with intrusion detection with door/window open alarm
Main door onto computer room floor	industrial grade lock	card access or biometric with intrusion detection with door open alarm	card access or biometric with intrusion detection with door open alarm	Single person interlock, portal or other hardware designed to prevent piggybacking or pass back of access credential
Bullet resistant walls, windows & doors				
Security Counter in Lobby	No requirement	No requirement	Level 3 (min)	Level 3 (min)
CCTV Monitoring				
Restricted areas and perimeter (e.g., building perimeter, generators, computer room, MEP rooms, telecommunications rooms, entrance rooms)	Not required	Not required	Yes	Yes
Access Controlled Doors	Not required	Yes	Yes	Yes
CCTV				
CCTV Recording of all activity on all cameras	Not required	Not required	Yes; digital	Yes; digital
Recording rate (frames per second)	No requirement	No requirement	20 frames/sec (min)	20 frames/sec (min)

	1 (A_1)	2 (A_2)	3 (A_3)	4 (A_4)
Structural				
Facility design to International Building Code (IBC) Seismic Design Category (SDC) requirements	Per local country standards for the building location (at minimum) or IBC SDC requirements for building location (if they exceed local requirements)	Per local country standards for the building location (at minimum) or IBC SDC requirements for building location (if they exceed local requirements)	Per local country standards for the building location (at minimum) or IBC SDC requirements for building location (if they exceed local requirements)	Per local country standards for the building location (at minimum) or IBC SDC-C requirements or higher for building location (if they exceed local requirements)
Site Specific Response Spectra - Degree of local Seismic accelerations	No requirement	No requirement	with Operation Status after 10% in 50-year event	with Operation Status after 5% in 100-year event
Importance factor - assists to ensure greater than code design	I=1	I=1.5	I=1.5	I=1.5
Telecommunications equipment racks/cabinets anchored to base or supported at top and base or equipped with seismic platforms or other protective measures	No requirement	Yes	Yes	Yes
Deflection limitation on telecommunications equipment within limits acceptable by the electrical attachments	Not required	Not required	Yes	Yes
Bracing of electrical conduits runs and cable trays	per code	per code w/ Importance	per code w/ Importance	per code w/ Importance
Bracing of mechanical system major duct runs	per code	per code w/ Importance	per code w/ Importance	per code w/ Importance
Floor loading capacity superimposed live load	7.2 kPa (150 lbf/ft^2).	8.4 kPa (175 lbf/ft^2)	12 kPa (250 lbf/ft^2)	12 kPa (250 lbf/ft^2)
Floor hanging capacity for ancillary loads suspended from below	1.2 kPa (25 lbf/ft^2)	1.2 kPa (25 lbf/ft^2)	2.4 kPa (50 lbf/ft^2)	2.4 kPa (50 lbf/ft^2)
Concrete Slab Thickness at ground	127 mm (5 in)	127 mm (5 in)	127 mm (5 in)	127 mm (5 in)
Minimum concrete topping over flutes for equipment anchorage when concrete filled metal deck structure used for elevated floors	102 mm (4 in)	102 mm (4 in)	102 mm (4 in)	102 mm (4 in)
Building LFRS (Shearwall/Braced Frame/Moment Frame) indicates displacement of structure	Steel/Concrete Moment Frame	Concrete Shearwall / Steel Braced Frame	Concrete Shearwall / Steel Braced Frame	Concrete Shearwall / Steel Braced Frame
Building Energy Dissipation - Passive Dampers/Base Isolation (energy absorption)	Minimum code requirements	Minimum code requirements	passive dampers for IBC Seismic Design Category D or higher	passive dampers/base isolation for IBC Seismic Design Category D or higher
Construction of Floors above ground level. (Steel structures with concrete filled metal decks are more easily upgraded for intense loads in Battery/UPS rooms. (Also, better for installing floor anchors).	PT concrete	CIP Mild Concrete	Steel Deck & Fill	Steel Deck & Fill

Table 13: Reference guide (electrical)

	1 (E_1)	2 (E_2)	3 (E_3)	4 (E_4)
ELECTRICAL				
General				
System allows concurrent maintenance	Not required	Not required but preferred for critical parts of infrastructure	Yes	Yes
Fault Tolerant	Not required	Not required	Not required	Yes
Power System Analysis	Up-to-date short circuit study, coordination study, and arc flash analysis	Up-to-date short circuit study, coordination study, and arc flash analysis	Up-to-date short circuit study, coordination study, arc flash analysis, and load flow study	Up-to-date short circuit study, coordination study, arc flash analysis, and load flow study
Computer & Telecommunications Equipment Power Cords	Single Cord Feed with 100% capacity	Single Cord Feed with 100% capacity	Redundant Cord Feed with 100% capacity on remaining cord or cords	Redundant Cord Feed with 100% capacity on remaining cord or cords
Utility				
Utility Entrance	Single Feed	Single Feed	Minimum 1 active, 1 standby. Same substation allowed. Self-generation allowed	Minimum 2 active. Different substation. Self-generation allowed
Main Utility Switchboard				
Service	Shared	Shared	Dedicated	Dedicated
Construction	Panel board with bolt on circuit breakers	Switchboard with stationary circuit breakers	Switchboard with draw out circuit breakers	Switchgear with draw out circuit breakers
Surge Suppression	Not required	Not required	Yes	Yes

	1 (E_1)	2 (E_2)	3 (E_3)	4 (E_4)
Uninterruptible Power Supply System				
Redundancy	N	N+1 equipment level, single path	N+1 (N for active, N for passive path)	2N / N+N (N for each active path)
Topology	Single or Parallel-Modules	Parallel Modules	Distributed Redundant Modules or Block Redundant System	Distributed Redundant Modules or Block Redundant System
Automatic Bypass	Not required	Yes, with non-dedicated feeder to automatic bypass	Yes, with dedicated feeder to automatic bypass	Yes, with dedicated feeder to automatic bypass
Maintenance Bypass Arrangement	Not required	Non dedicated maintenance bypass feeder to UPS output switchboard	Dedicated maintenance bypass feeder serving UPS output switchboard	Dedicated maintenance bypass feeder serving UPS output switchboard
Battery String	Single or common string for multiple modules	Single or common string for multiple modules modular UPS. Dedicated string for standalone modules	Dedicated string for each module	Dedicated string for each module
Battery type	5 or 10-year design life batteries or flywheel	5 or 10-year design life batteries or flywheel	5 or 10-year design life batteries or flywheel	5 or 10-year design life batteries or flywheel
Battery minimum back up time with design load at end of battery life	10 Minutes or flywheel capacity	10 Minutes or flywheel capacity	10 Minutes or flywheel capacity	10 Minutes or flywheel capacity
Battery Monitoring System	Not required	Not required	String level by UPS System	String level by UPS system or centralized battery monitoring system
Power Distribution Unit				
Transformer	Standard high efficiency	Standard high efficiency	K-Rated or harmonic cancelling, high efficiency	K-Rated or harmonic cancelling, low Inrush high efficiency
Automatic Static Transfer Switch				
Dedicated over-current protection device on input of static bypass	Not required	Not required	Yes	Yes
Maintenance Bypass	Not required	Not required	Yes	Yes

	1 (E_1)	2 (E_2)	3 (E_3)	4 (E_4)
Grounding and bonding				
Lightning protection system	Based on risk analysis as per NFPA 780 and insurance requirements.	Based on risk analysis as per NFPA 780 and insurance requirements.	Yes	Yes
Lighting fixtures neutral isolated from service entrance derived from lighting transformer for ground fault isolation	Not required	Not required	Yes	Yes
Data center bonding and grounding infrastructure in computer room	As required by ANSI/TIA-607-C	As required by ANSI/TIA-607-C	As required by ANSI/TIA-607-C	As required by ANSI/TIA-607-C
Computer Room Emergency Power Off (EPO) System				
Installation	If required by AHJ, type as required with cover guard and warning label.	If required by AHJ, type as required with cover guard and warning label.	If required by AHJ, type as required with cover guard and warning label.	If required by AHJ, type as required with cover guard and warning label.
Test Mode	Yes	Yes	Yes	Yes
Alarm	Yes	Yes	Yes	Yes
Disable/enable switch	As allowed by local codes	As allowed by local codes	As allowed by local codes	As allowed by local codes
Central Power Monitoring				
Monitored Points	Not required	Utility UPS Generator	Utility, Main Transformer, UPS, Generator, Feeder Circuit Breakers, Automatic Static Transfer Switch, PDU, Automatic Transfer Switches	Utility, Main Transformer, UPS, Generator, Feeder Circuit Breakers, Automatic Static Transfer Switch, PDU, Automatic Transfer Switches, Surge Protection Device, Critical Load Branch Circuits
Notification Method	Not required	Control Room Console	Control Room Console, Pager, Email, and/or text message	Control Room Console, Pager, Email, and/or text message to multiple facility personnel
Battery Room				
Separate from UPS Equipment Rooms	Not required	Not required	Battery in UPS room allowed if allowed by code, preference for separate battery room	Battery in UPS room allowed if allowed by code, preference for separate battery room
Individual Battery Strings Isolated from Each Other	Not required	Not required	Yes	Yes
Shatterproof Viewing Glass in Battery Room Door or CCTV	Not required	Not required	Not required	Yes

	1 (E_1)	2 (E_2)	3 (E_3)	4 (E_4)
Standby Generating System				
Generator Sizing	If installed, sized for UPS & mechanical systems without redundancy	Sized for UPS & mechanical system without redundancy	Sized for total building load N+1 distributed redundancy	Sized for total building load with 2N distributed redundancy
Generators on Single Bus	Yes	Yes	Yes	No
Load bank				
Installation	No requirement	Provision for portable	Provision for portable	Provision for portable with a preference for permanent
Equipment Tested	No requirement	Generator	Generator UPS	Generator UPS
Auto Shutdown	Not required	Not required	Automatic upon failure of utility	Automatic upon failure of utility
Testing				
Factory Acceptance Testing	Not required	Not required	UPS and Generator Systems	UPS and Generator Systems, Generator controls, ASTS
Site circuit breaker testing	Not required	Not required	As per local code with a minimum of contact resistance test of all critical circuit breakers at the primary distribution of the electrical system	As per local code with a minimum of contact resistance test of all critical circuit breakers at the primary distribution of the electrical system
Commissioning	Not required	Component level	Component level and System level	Component level, system level, and integrated system including total outage testing
Equipment Maintenance				
Operation and Maintenance Staff	Offsite. On call.	Onsite Day Shift only. On-call at other times	Onsite 24 hrs M-F, on-call on weekends	Onsite 24/7
Preventative Maintenance	No requirement	Generator maintenance	Generator and UPS maintenance	Comprehensive preventative maintenance program
Facility Training Programs	No requirement	Limited training by manufacturer	Comprehensive training program for normal operation of equipment	Comprehensive training program for normal operation of equipment and manual operation of equipment during emergency operation

Table 14: Reference guide (mechanical)

	1 (M_1)	2 (M_2)	3 (M_3)	4 (M_4)
MECHANICAL				
General				
Redundancy for mechanical equipment (e.g., air conditioning units, coolers, pumps, cooling towers, condensers). These redundancy requirements extend to all support areas that are critical to the uninterrupted operation of the computer/server room.	Not required	N+1 redundancy for mechanical equipment. Loss of electrical supply path or water supply (where applicable) could lead to loss of cooling	N+1 redundancy for mechanical equipment to allow for concurrently maintainability. Temporary loss of electrical power or interruption of water supply (where applicable) will not cause loss of cooling, but may cause temperature to elevate within operational range of critical equipment. The switchover from N to +1 may be performed manually.	N+1 redundancy for mechanical equipment to allow for Fault Tolerance. Extended loss of supply path of power or piping (where applicable) will not cause loss of cooling outside operational range of critical equipment. The switch over from N to +1 should be fully automated
Routing of water or drain piping not associated with the data center equipment in data center spaces	Permitted but not recommended	Permitted but not recommended	Not permitted	Not permitted
Positive pressure in computer room and associated spaces relative to outdoors and non-data center spaces	Not required	Yes	Yes	Yes
Floor drains in computer room for condensate drain water, humidifier flush water, and sprinkler discharge water	Yes	Yes	Yes	Yes
Mechanical systems on standby generator	Not required	Yes	Yes	Yes
Humidity Control for Computer Room	Not required	De-humidification/humidification, where applicable, provided	De-humidification/humidification, where applicable, provided	De-humidification/humidification, where applicable, provided
ater-Cooled System				
Indoor Terminal Air Conditioning Units	No redundant air conditioning units	One redundant air conditioning unit per critical area	One additional air conditioning unit for every 5-8 units installed	One additional air conditioning unit for every 5-8 units installed
Electrical Service to Mechanical Equipment	Single path of electrical power to AC equipment	Single path of electrical power to AC equipment	N+1 configured to allow for concurrent maintenance	2N/N+N configured to allow for fault tolerance
Heat Rejection				
Piping Systems	Single path	Single path	Piping systems allow for concurrent maintenance	Piping systems provide fault tolerance

	1 (M_1)	2 (M_2)	3 (M_3)	4 (M_4)
Chilled Water & Air Cooled Systems				
Electrical Service to Mechanical Equipment	Single path of electrical power to AC equipment	Single path of electrical power to AC equipment	N+1 configured to be concurrently maintainable	2N/N+N configured to allow for fault tolerance
HVAC Control System				
HVAC Control System	Control system failure will interrupt cooling to critical areas	Control system failure will not interrupt cooling to critical areas but might prevent further control of temperature/humidity (steady state)	Control system design should be concurrently maintainable	Control system design should be fault tolerant
Power Source to HVAC Control System	Single path of electrical power to HVAC control system	Single path of electrical power to HVAC control system	Dual path of electrical power in N+1 configuration designed to be concurrently maintainable	Dual path of electrical power in 2N/N+N configuration designed for fault tolerance
Plumbing (for water-cooled heat rejection)				
Make-up Water	Single water supply, with no on-site back-up storage	Dual sources of water, or one source + on-site storage with a minimum equal to duration of generator fuel supply	Dual sources of water, or one source + on-site storage with a minimum equal to duration of generator fuel supply	Dual sources of water, or one source + on-site storage with a minimum equal to duration of generator fuel supply
Points of Connection to Condenser Water System	Single point of connection	Single point of connection	Two points of connection	Two points of connection
Fuel Oil System				
Onsite generator fuel storage	If generator is present, minimum belly/onboard fuel tank filled up to 80% capacity	24 hours as allowed by AHJ	72 hours as allowed by AHJ	96 hours as allowed by AHJ
Bulk Storage Tanks	Single storage tank	Single storage tanks	Multiple storage tanks	Multiple storage tanks
Storage Tank Pumps and Piping	Single pump and/or supply pipe	Multiple pumps, single supply pipes	Fuel supply designed for concurrently maintainability	Fuel supply designed for fault tolerance
F re Suppression				
Fire detection system	Yes	Yes	Yes	Yes
Fire sprinkler system	When required	Pre-action (when required)	Pre-action (when required)	Pre-action (when required)
Gaseous suppression system for computer rooms and entrance rooms containing active ICT equipment	No requirement above AHJ	No requirement above AHJ	When used, clean agents should be allowed by local code. Alternative systems (e.g., hypoxic, mist) are allowed	When used, clean agents should be allowed by local code. Alternative systems (e.g., hypoxic, mist) are allowed
Early Warning Smoke Detection System for computer rooms and entrance rooms containing active ICT equipment	No requirement above AHJ	Yes	Yes	Yes
Water Leak Detection System for computer rooms and entrance rooms containing active ICT equipment	No requirement above AHJ	Yes	Yes	Yes

ANNEX G (INFORMATIVE) DATA CENTER DESIGN EXAMPLES

This annex is informative only and is not part of this Standard.

G.1 Small data center design example

One example layout for a small data center is shown below. This is an example of a data center that is small enough to be supported by a main distribution area and no horizontal distribution areas (HDAs).

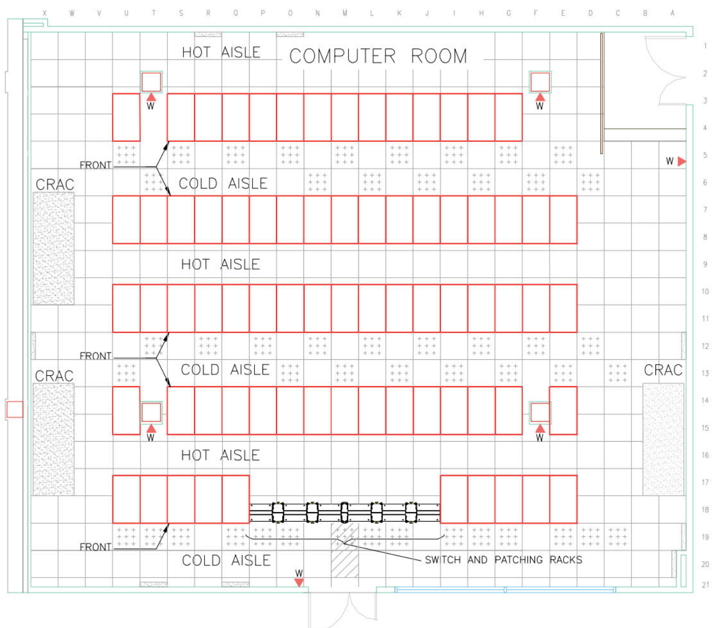


Figure 17: Computer room layout showing “hot” and “cold” aisles

This computer room space is about 178 square meters (1,920 square feet). It has 73 server cabinets in the equipment distribution areas (EDAs) and six 19” racks in the main distribution area (MDA). The six MDA racks are the six ‘SWITCH AND PATCHING RACKS’ at the bottom of the drawing. It was not necessary to put the MDA in the center of the computer room because length limitations were not an issue. However, cable lengths and cable congestion in the aisles perpendicular to the cabinet aisles could have been reduced by placing the MDA in the center of the room instead.

The MDA supports the HC for horizontal cabling to the EDAs. In a data center with a high density of cabling to the equipment cabinets, it would probably be necessary to have HDAs to minimize cable congestion near the MDA.

The rack and cabinet rows are parallel to the direction of under floor airflow created by the Computer Room Air Conditioning (CRAC) units. Each CRAC is located facing the “hot” aisles to allow more efficient return air to each CRAC unit.

Server cabinets are arranged to form alternating “hot” and “cold” aisles.

Telecommunications cables are run in wire basket trays in the “hot” aisle. Power cables are run under the access floor in the “cold” aisles.

The computer room is separate from the Network Operations Center (NOC is not shown) for access and contaminant control.

G.2 Corporate data center design example

The following example is for an Internet or web hosting data center used to house computer and telecommunications equipment for multiple corporate web sites.

The corporate data center in this example has two floors of about 4,140 m^2 (44,500 ft^2) each. This data center is an example of a data center with several HDAs, each differentiated primarily by the type of systems that they support. Due to the density of cabling to the personal computer based servers, these systems are served by two HDAs, each supporting only 24 server cabinets. Seven additional HDAs are planned to support additional server cabinets. Thus, HDAs may be required not only for different functional areas, but also to minimize cable congestion in the HDA. Each HDA was designed to support a maximum of 2,000 4-pair balanced twisted-pair cables.

Note that the Internet and PC HDAs are located near the center of the rows that they support to ensure that lengths for category 8 cabling remains within 24 meters for permanent links and 30 meters for channels. The category 8 cabling can support 25GBASE-T and 40GBASE-T.

The 1st floor includes the electrical rooms, mechanical rooms, storage rooms, loading dock, security room, reception area, operations center, and entrance room.

The computer room is on the 2nd floor and is entirely on access floor. All telecommunications cabling is run under the access floor space in wire-basket cable trays. In some locations where the volume of cables is the greatest and where they do not impede airflow, the cable trays are installed in two layers. The drawing below shows the 2nd floor computer room with cable trays. In the example below, the cable trays are in blue and the IT cabinets and equipment are in gray.

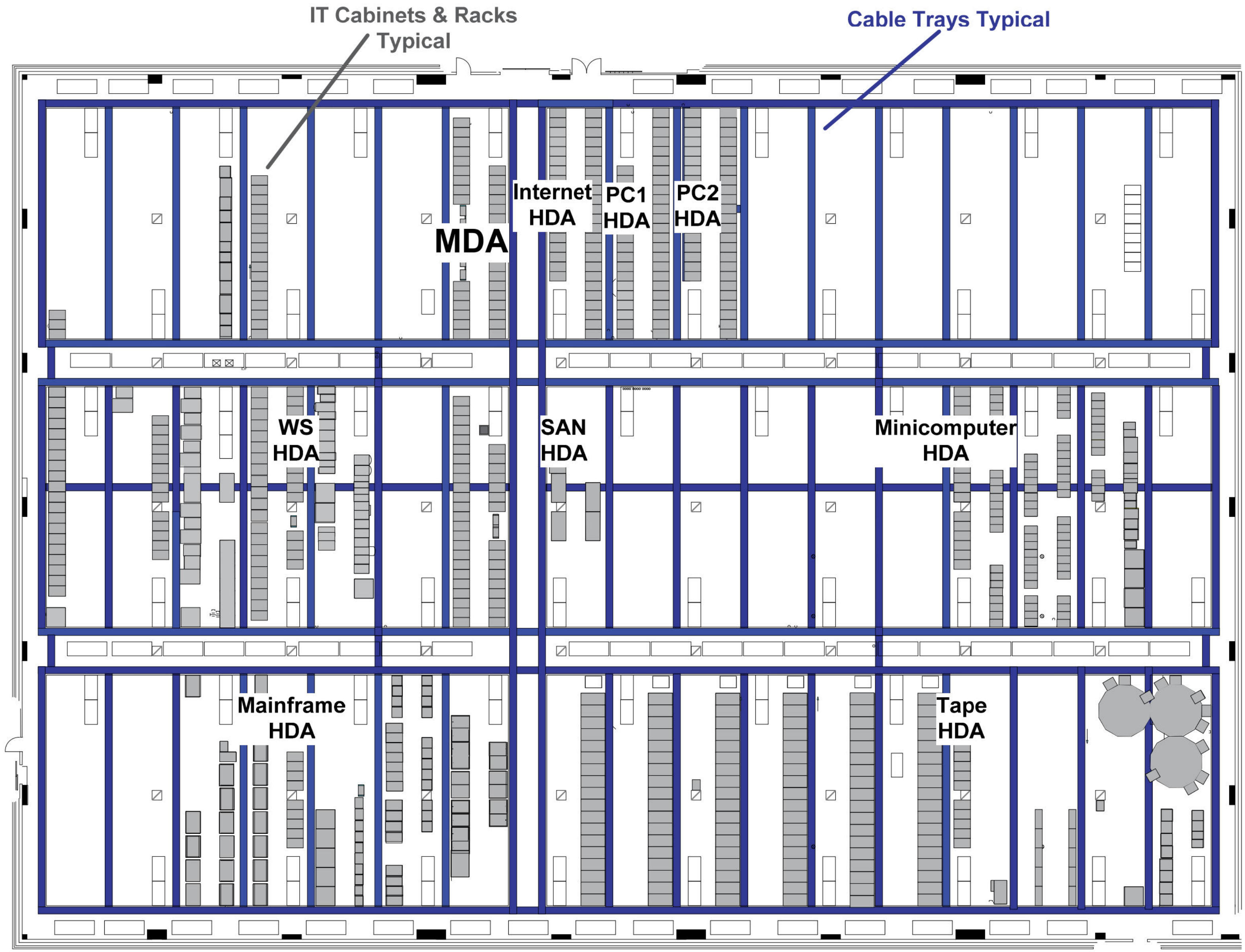


Figure 18: Example of corporate data center

Telecommunications cabling is installed in the “hot” aisles behind the server cabinets. Electrical cabling is installed in the “cold” aisles in front of the server cabinets. Both telecommunications cabling and electrical cabling follow the main aisles in the east/west direction, but follow separate pathways to maintain separation of power and telecommunications cabling.

The locations of the Entrance Room on the 1st floor and MDA on the 2nd floor are carefully positioned so that T-1 and T-3 circuits can be terminated on equipment anywhere in the computer room.

Cabinets for rack-mounted servers have standardized cabling that includes multimode fiber and balanced twisted-pair. Administration is somewhat simplified if cabinets have a standard cabling configuration.

In this data center, due to the very wide variety of cabling requirements for floor standing systems, it was not possible to develop a standardized configuration for equipment outlets in ZDAs.

G.3 Internet data center design example

The Internet data center in this example has one floor of approximately 9,500 m^2 (102,000 ft^2) with a computer room of about 6400 m^2 (69,000 ft^2). It is an example of a data center where HDAs are differentiated primarily by the area served rather than the type of systems that they support. The drawing below shows the data center floor plan with cable trays. MDA and HDA racks are shown but customer racks and cabinets are not. Cable trays and ladders are in blue. Distributor racks are black. Architectural features such as stairs, doors, and permanent walls are in red.

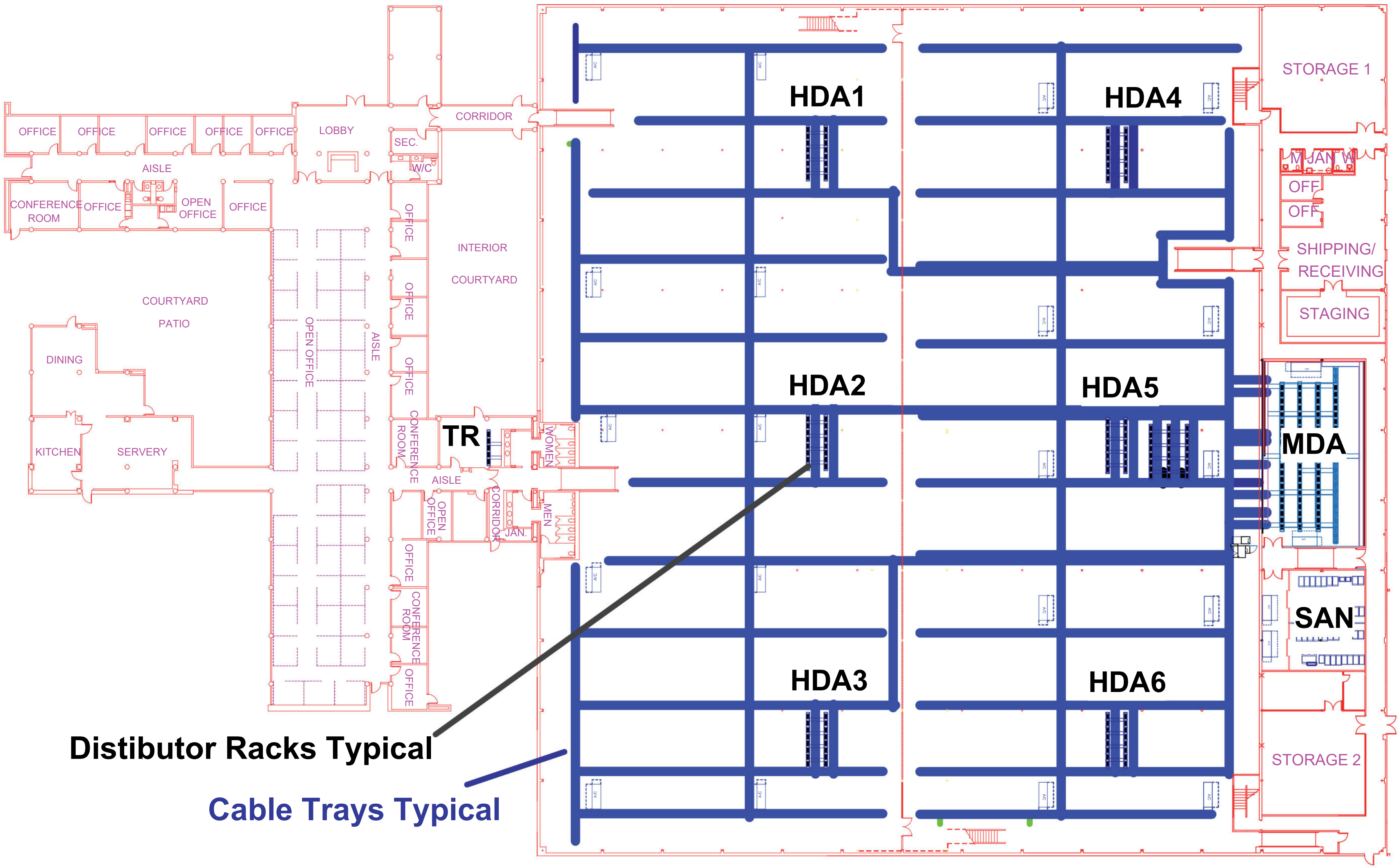


Figure 19: Example of Internet data center

The main distribution area (MDA) incorporates the function of the entrance room and the main cross-connect. It accommodates 50 access provider racks and 20 racks for the main cross-connect space. This room is supported by two dedicated PDUs, two dedicated computer room air conditioning units, and is on access floor. The MDA is in a dedicated room with a separate entrance that allows access and service providers to work in this room without entering the customer spaces in the main computer room. The locations of the MDA and HDAs were planned to ensure that circuit lengths for T-1 and T-3 circuits will not be exceeded for circuits to any rack in the computer room.

Automated tape libraries, storage servers, and control equipment for storage services are in a dedicated SAN room adjacent to the MDA. This equipment is provided and managed by third parties, not by the owner of the internet data center. A separate room for this equipment allows storage service providers to manage their equipment without entering the main computer room.

The computer room space has 4,300 customer racks. The customer space is supported by six HDAs to limit the volume of cable in the under floor cable trays. Each HDA supports approximately 2,000 balanced twisted-pair connections. These HDAs are in the center of the spaces they serve to minimize cable lengths. Cabling from the HDAs to the customer racks is standardized to simplify administration. However, additional cabling may be run to customer racks as required.

Telecommunications cabling to storage and staging areas east of the computer room are supported from the MDA. Telecommunications cabling for the offices west of the computer room are supported by a telecommunications room (TR).

ANNEX H (INFORMATIVE) CABLING GUIDELINES FOR DATA CENTER FABRICS

This annex is informative only and is not part of this Standard.

H.1 Traditional Switch Architecture

Figure 20 provides an example of the traditional three-tier data center switch architecture.

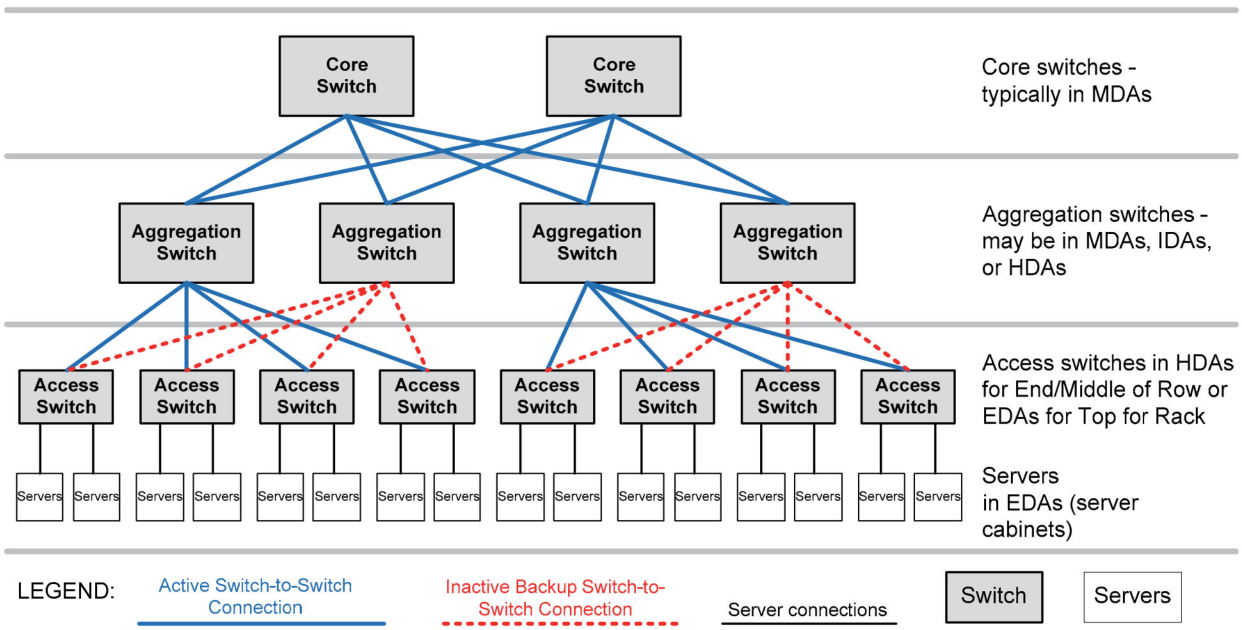


Figure 20: Example of traditional three-tier data center switch architecture

Some of the characteristics of the traditional three-tier switch architecture are:

- Backup connections (the dashed red lines in figure 20) to access switches are not active due to spanning tree protocols used to prevent routing loops (some protocols do not have this limitation)
- Connections are typically over-subscribed (i.e., more traffic assigned to the link than the bandwidth capacity of the link)
- When access switches are located in the EDA (i.e., top of rack), more switch ports may be available in each cabinet than necessary
- Traffic between two access switches may need to traverse as many as three intermediate switches

The traditional architecture is well-suited for traffic between servers on the same access switch and from servers to external destinations. However, it isn't suitable for large virtualized data centers where compute and storage servers may be located anywhere in the data center.

All cabling for the traditional architecture follows the hierarchical cabling topology specified in this Standard. See figure 21 for an example.

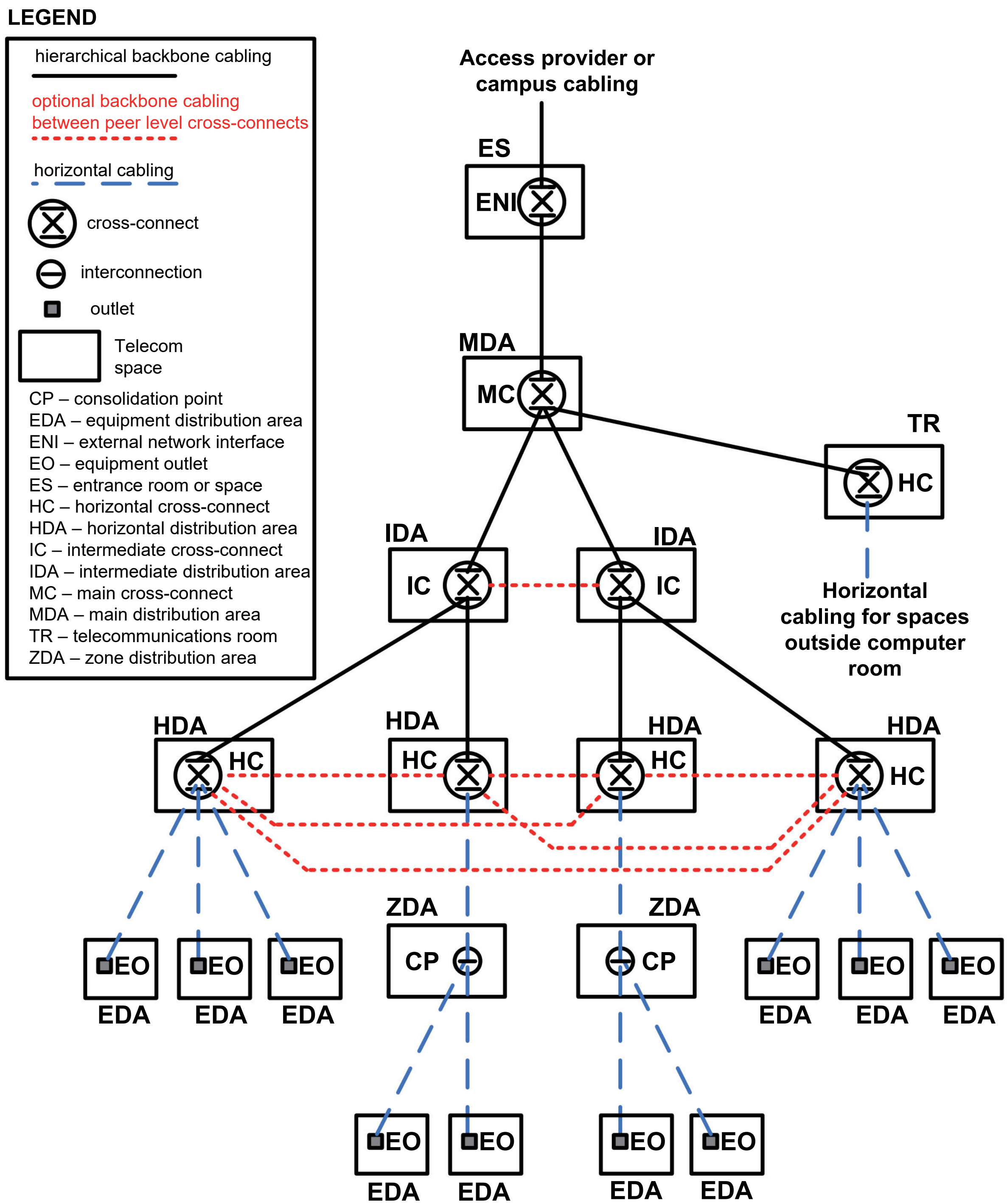


Figure 21: Example of ANSI/TIA-942-B cabling topology

H.2 Multiple Connections

Compute and storage servers often have multiple connections to provide redundancy, additional bandwidth, or to support different functions. The connections may be to a single switch, to multiple switches within the same network, or to multiple switches in different networks. See figure 22.

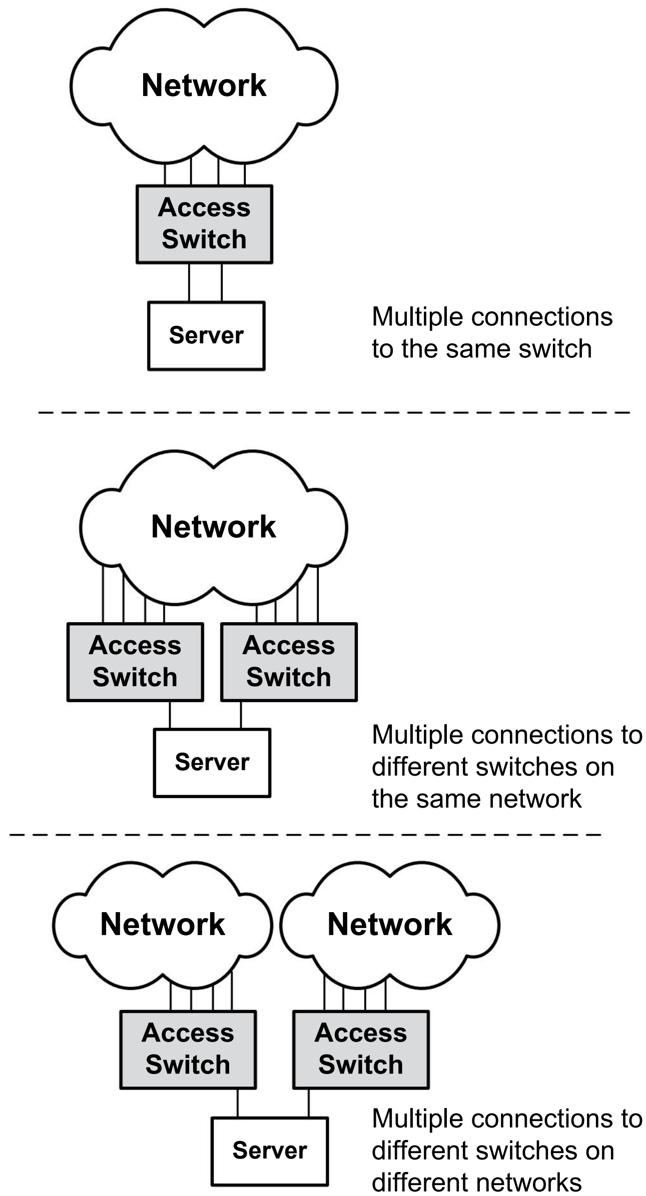


Figure 22: Examples of redundant connectivity

H.3 Data Center Switch Fabrics

Data center switch fabric architectures are intended to provide low-latency and high-bandwidth communication between any two points in the switch fabric. Data center switch fabric architectures typically use only one or two tiers of switches. These switches have large numbers of connections to other switches. These connections are all active to provide multiple paths that minimize latency and to provide maximum switch fabric bandwidth.

Data center switch fabric architectures can be accommodated using the cabling topology specified in this Standard. Some data center switch fabric architectures require backbone cabling between peer level distributors, for example between HDAs (see figure 21). Some require direct cabling between switches located in different EDAs (for example, between top-of-rack/cabinet switches). Direct attach cabling between switches in EDAs should adhere to the guidelines specified in 7.3.4.

In all of the architectures described in this annex, compute and storage servers may be connected to multiple access switches for redundancy.

H.3.1 Data center fabric fat-tree

Figure 23 is an example of the fat-tree switch fabric architecture (also called the leaf and spine switch architecture). This architecture has no more than one switch between any two access switches and can be non-blocking by providing sufficient bandwidth from each access switch to the interconnection switches.

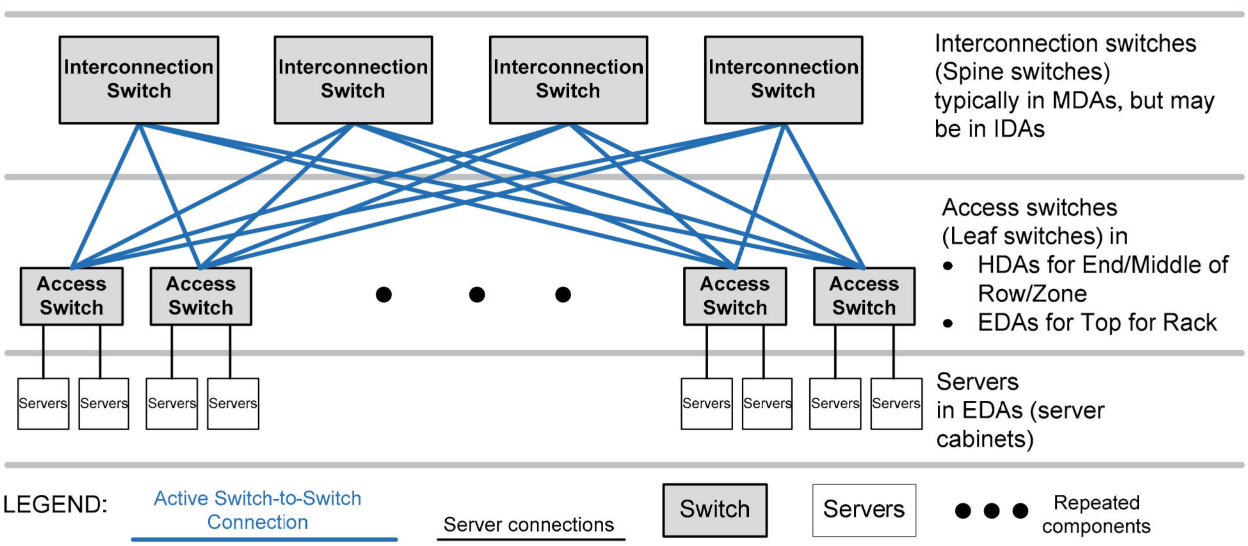


Figure 23: Fat-tree example

In the fat-tree architecture, all access switches are connected to every interconnection switch. The interconnection switches are typically located in one or more MDAs and don't need to be connected to each other. If the data center switch fabric only serves a subset of the data center supported by one or more IDAs, the interconnection switches may be located in IDAs.

The access switches may be in the HDAs or EDAs. HDAs can serve a single row or multiple rows of cabinets.

For this architecture to be non-blocking, the sum of the bandwidth of all server connections on each access switch must be less than or equal to the sum of the bandwidth of all of the uplinks from the access switch to the interconnection switches. Specifically, an access switch with twenty-four 10 Gbps server ports will need at minimum of: twenty-four 10 Gbps, six 40 Gbps, or three 100 Gbps uplinks.

This architecture requires more cabling than the traditional three-tier architecture, but all of the cabling follows the standard ANSI/TIA-942-B cabling topology.

There will be a limit on the size of the fabric imposed by the number of ports available on the interconnection switches. For this reason, the fat-tree architecture will typically be implemented in a large data center with the access switches located in HDAs.

A variant of the fat-tree that extends the port-interfaces of the switches to top-of-rack/cabinet port extenders is shown in figure 24.

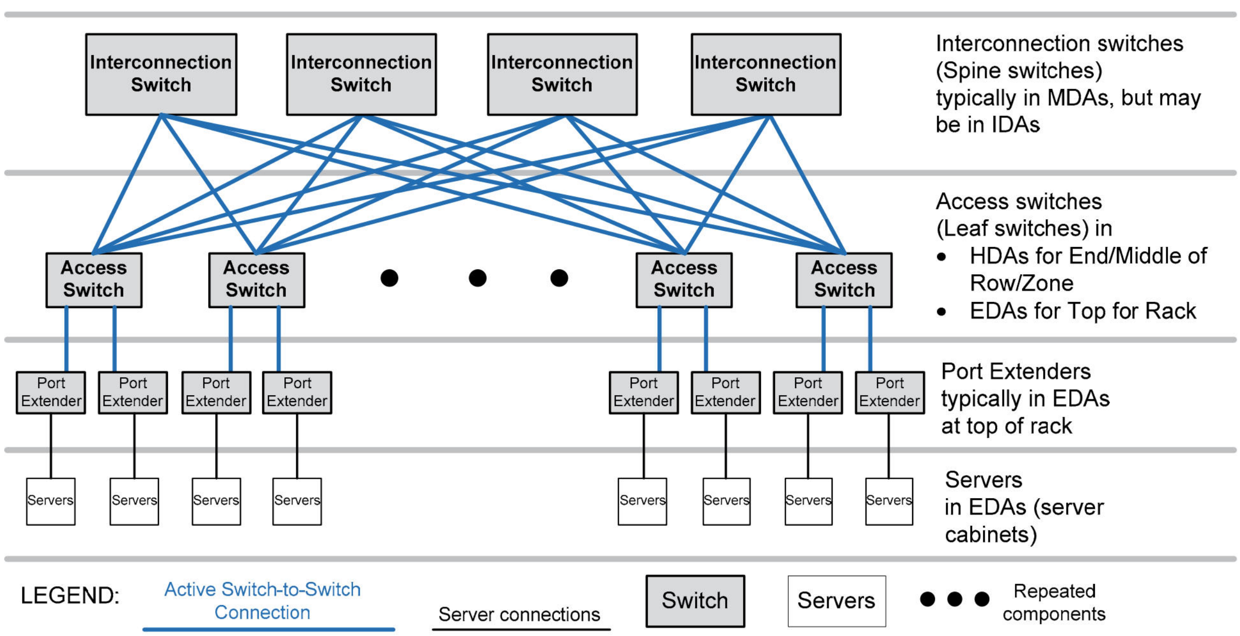


Figure 24: Fat-tree with port extenders example

Port extenders are physical extensions of access switches to which they are attached. Typically, they map many lower-speed ports for server communication to fewer higher-speed ports on the access switch. For the switch fabric to be non-blocking, the connection between the access switch and the port extender must have as much bandwidth as the total bandwidth of the server ports on the port extender. The connection between the port extender and the access switch may use structured cabling depending on the protocol used for this connection.

See figure 25 for an example of structured cabling supporting a fat-tree switch fabric architecture.

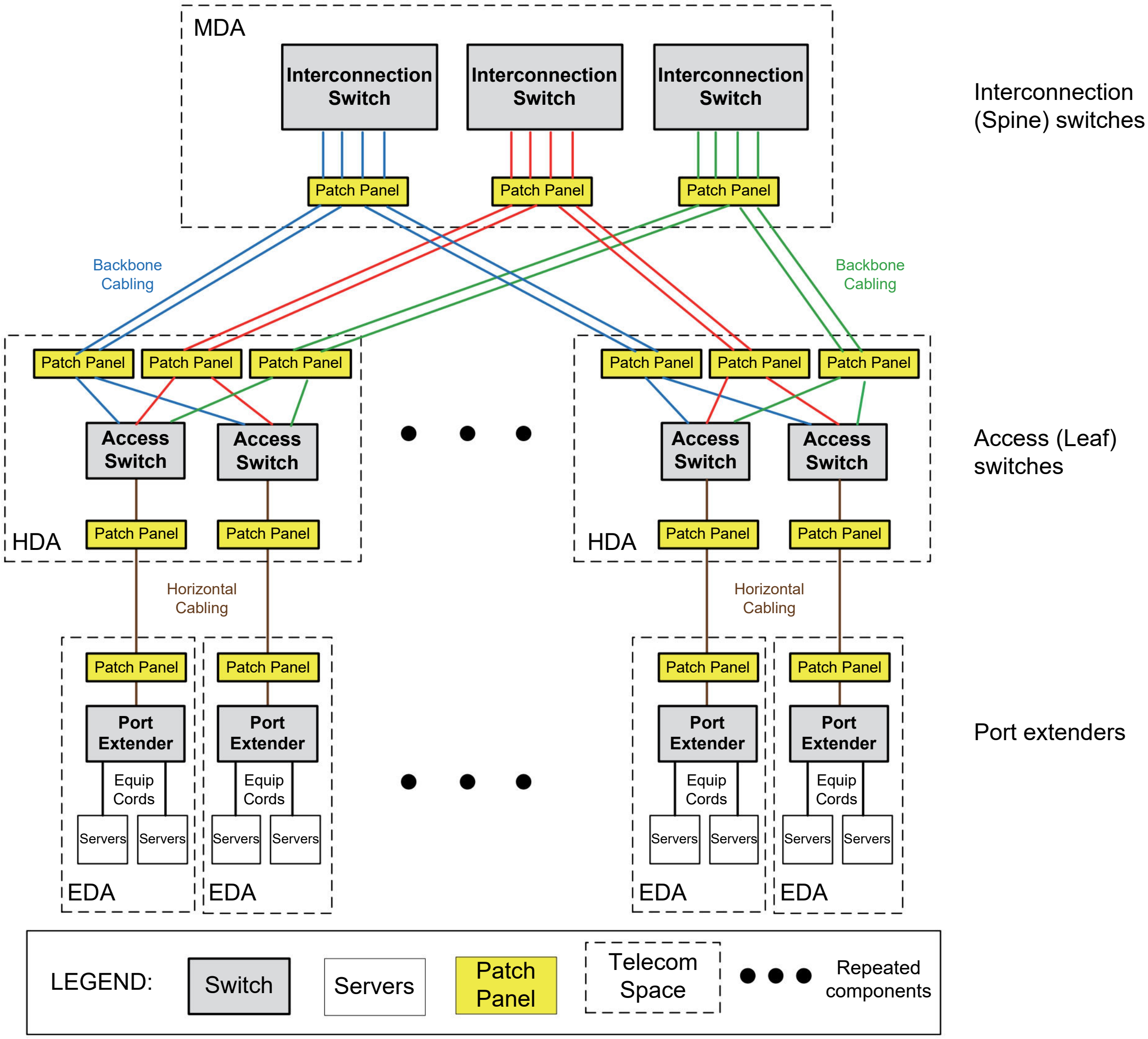


Figure 25: Example of use of structured cabling for fat-tree switch architecture

Larger switch fabrics may be created by interconnecting fat-trees (or pods) using a second layer of inter-connection (or spine) switches. See figure 26.

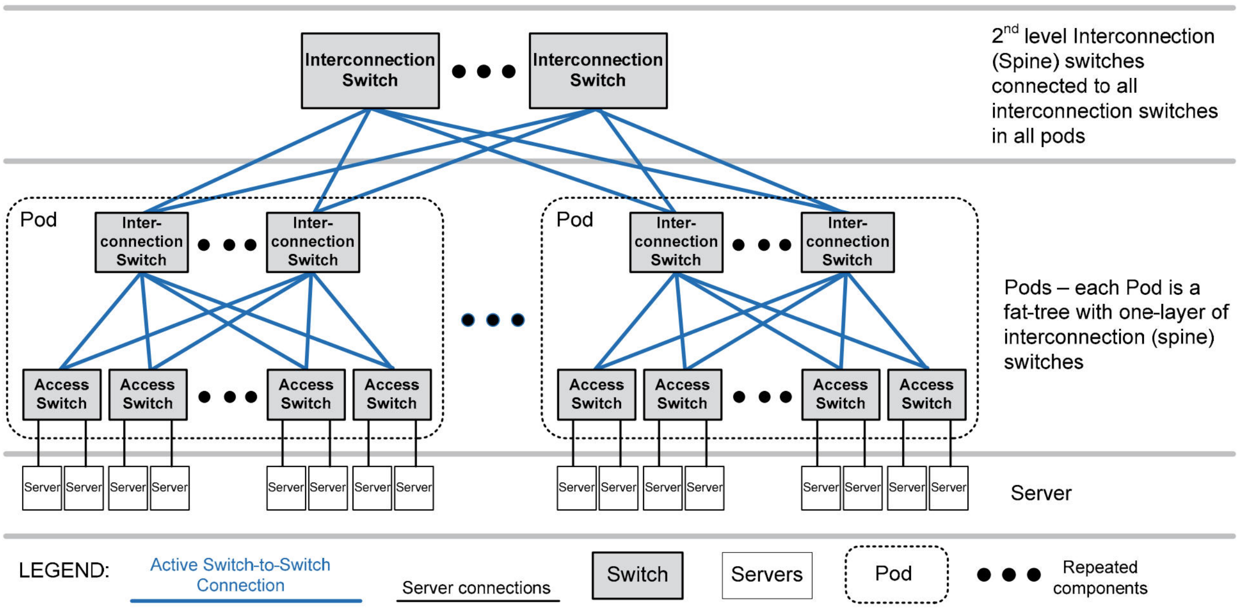


Figure 26: Interconnected fat-tree pods example

H.3.2 Data center fabric full-mesh

Figure 27 is an example of the full-mesh switch fabric architecture. This architecture has no intermediate switches between any two access switches and is typically non-blocking.

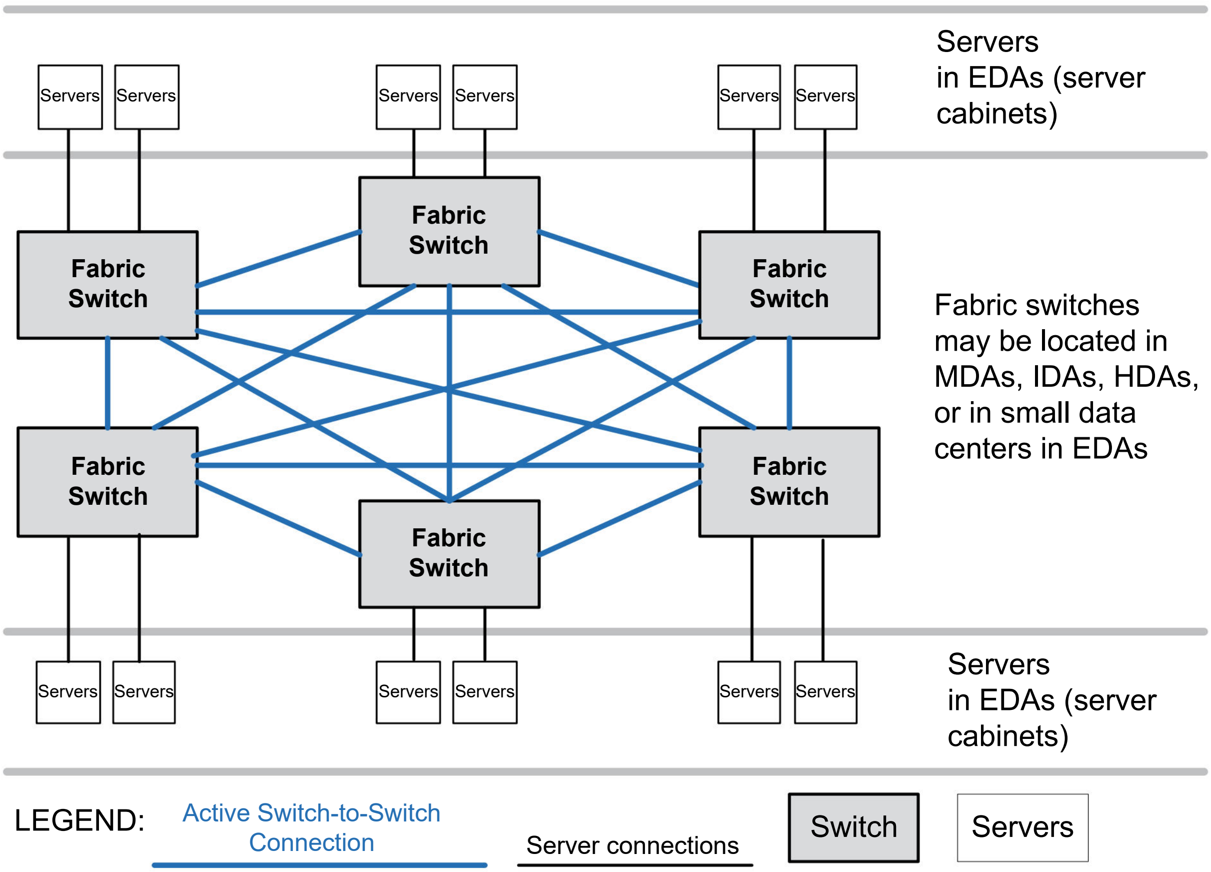


Figure 27: Full-mesh example

In the full-mesh architecture, all switches are connected to every other switch. To be a non-blocking fabric, the sum of the bandwidth on server ports on each switch must be less than or equal to the sum of the bandwidth on ports to other switches.

The architecture does not scale well because of the requirement that each switch connect to every other switch. For this reason, the switches are typically not located in the EDA (i.e., not implemented using top-of-rack/cabinet switches) except in small data centers.

Cabling for the full-mesh architecture should follow the ANSI/TIA-942-B cabling scheme. It may require the optional backbone cabling between peer level cross-connects (e.g., HDA-to-HDA). See Figure 28 for an example of structured cabling supporting a full-mesh switch fabric architecture.

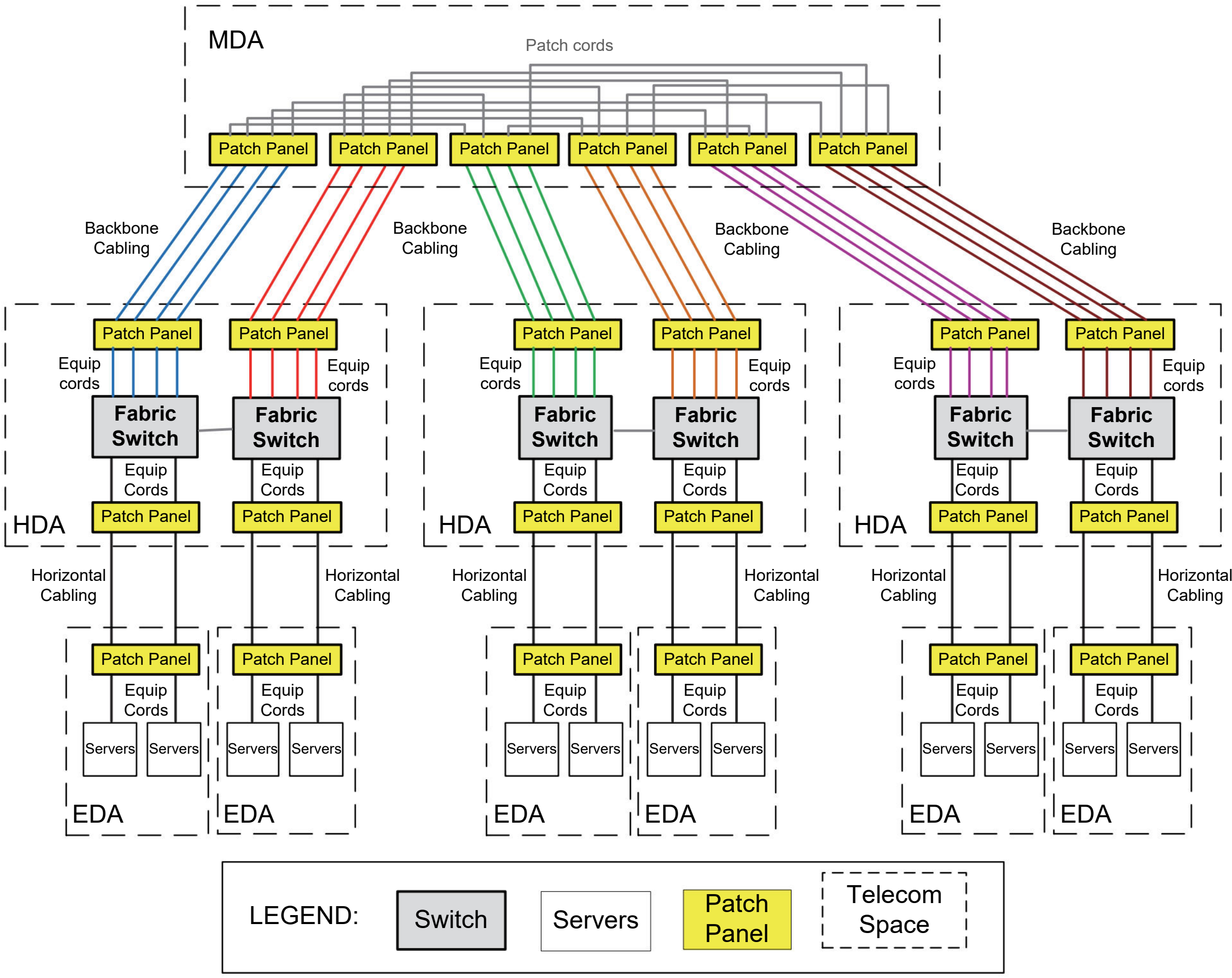


Figure 28: Example of use of structured cabling for full-mesh switch architecture

H.3.3 Data center fabric inter-connected meshes

Figure 29 is an example of the interconnected mesh switch fabric architecture. This architecture has between one and three intermediate switches between any two access switches. It is typically non-blocking within a pod (a portion of a data center) and might not be non-blocking between pods.

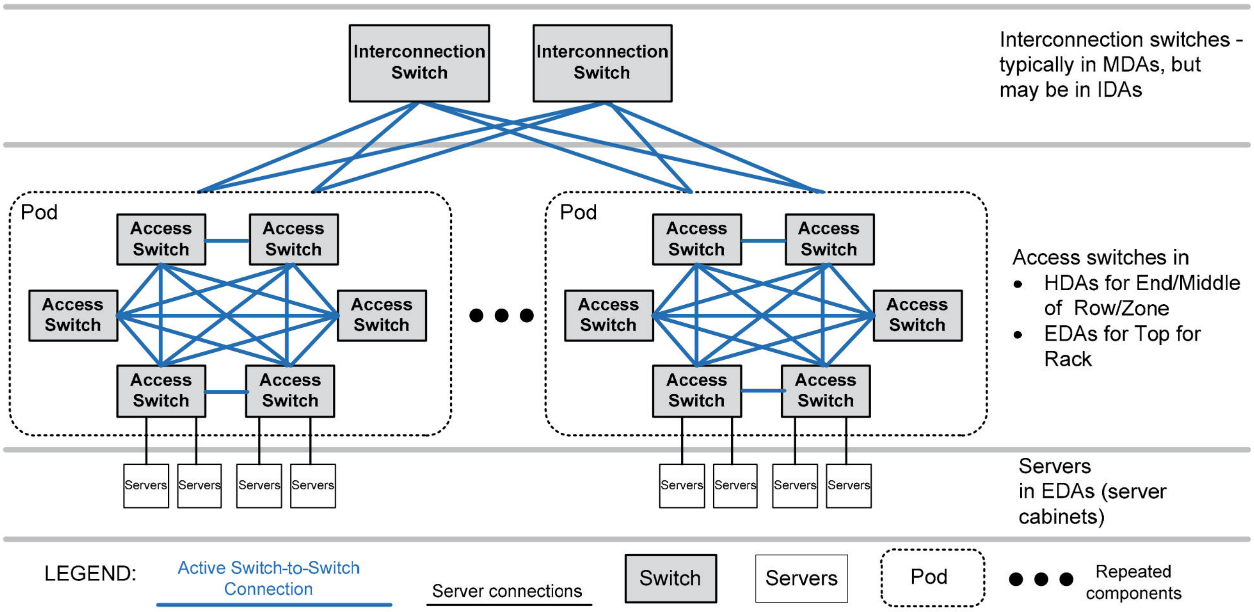


Figure 29: Interconnected meshes example

In this example, the architecture within a pod is a full-mesh. This pod might contain systems that are all dedicated to related applications.

If the interconnection switches are connected to all access switches in all pods, the maximum number of intermediate switches between access switches in different pods is one switch. Otherwise, the maximum number of intermediate switches between access switches in different pods is three.

The access switches may be in the HDAs or EDAs. HDAs can serve a single row or multiple rows of cabinets.

Cabling for the interconnected meshes architecture should follow the ANSI/TIA-942-B cabling scheme. It can use the optional HDA-to-HDA backbone cabling if the access switches are located in the HDAs. Additionally, cabling between equipment in EDAs may be used if the access switches are located in the EDAs. If direct attach cabling is used, it should be no greater than 7 m (23 ft) and should be between cabinets/racks in the same row. This direct attach cabling should be routed in cable management or accessible pathways, and not interfere with fixed cabling.

See figure 30 for an example of structured cabling supporting an interconnected mesh switch fabric architecture.

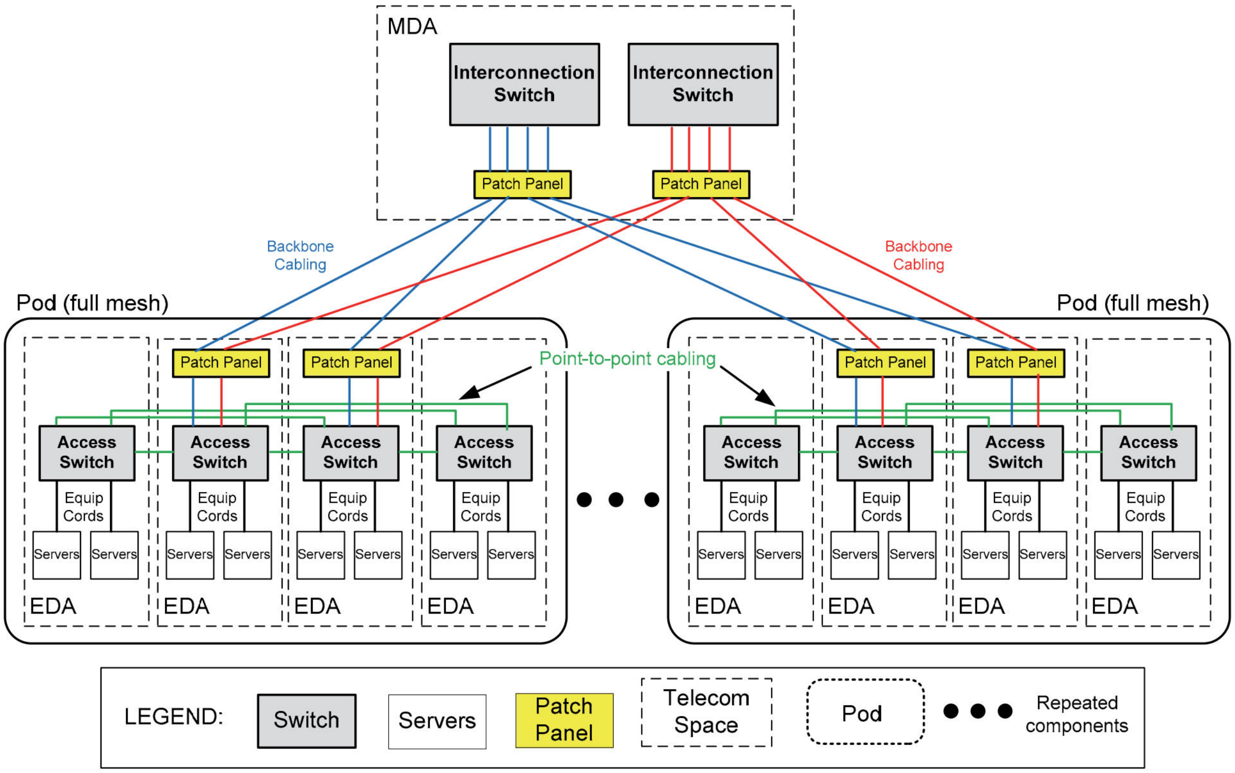


Figure 30: Example of use of structured cabling for interconnected mesh fabric

H.3.4 Data center fabric centralized switch

Figure 31 is an example of the centralized switch fabric architecture. With this architecture, the fabric is implemented within the backplane of the switch. There may be one or more switches if redundancy is desired. The architecture is non-blocking and has no switch-to-switch latency.

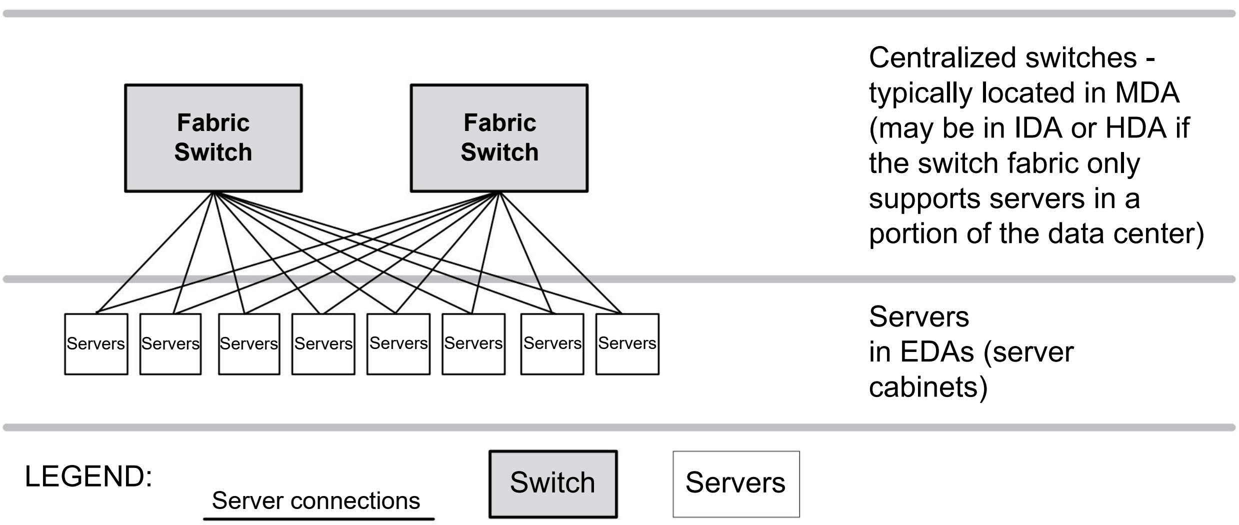


Figure 31: Centralized switch example

With the centralized switch architecture, all compute and storage servers are connected to all fabric switches and all connections are active.

The switches may be located in any distributor that supports horizontal cabling to all of the servers. This is typically the MDA, but it may be an IDA or HDA if the data center switch fabric only supports a portion of the data center. The switches do not need to be interconnected.

Cabling for the centralized switch architecture follows the ANSI/TIA-942-B cabling scheme.

This architecture, while being simple and having very low latency, does not scale well because it cannot support more servers than the maximum number of ports available on a single switch.

See figure 32 for an example of structured cabling supporting a centralized switch fabric architecture.

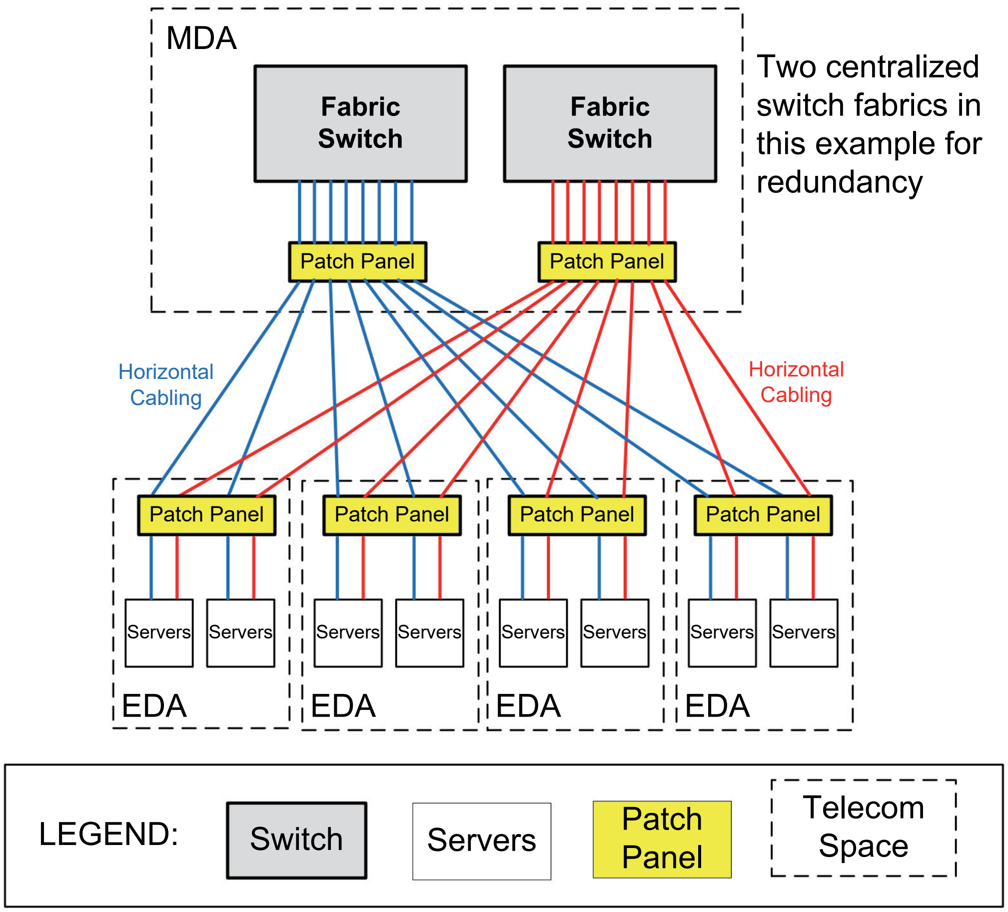


Figure 32: Example of use of structured cabling for centralized switch fabric

The scalability of a single switch can be alleviated to some extent by connecting several switches into one large virtual switch.

H.3.5 Data center fabric virtual switch

Figure 33 is an example of the virtual switch fabric architecture.

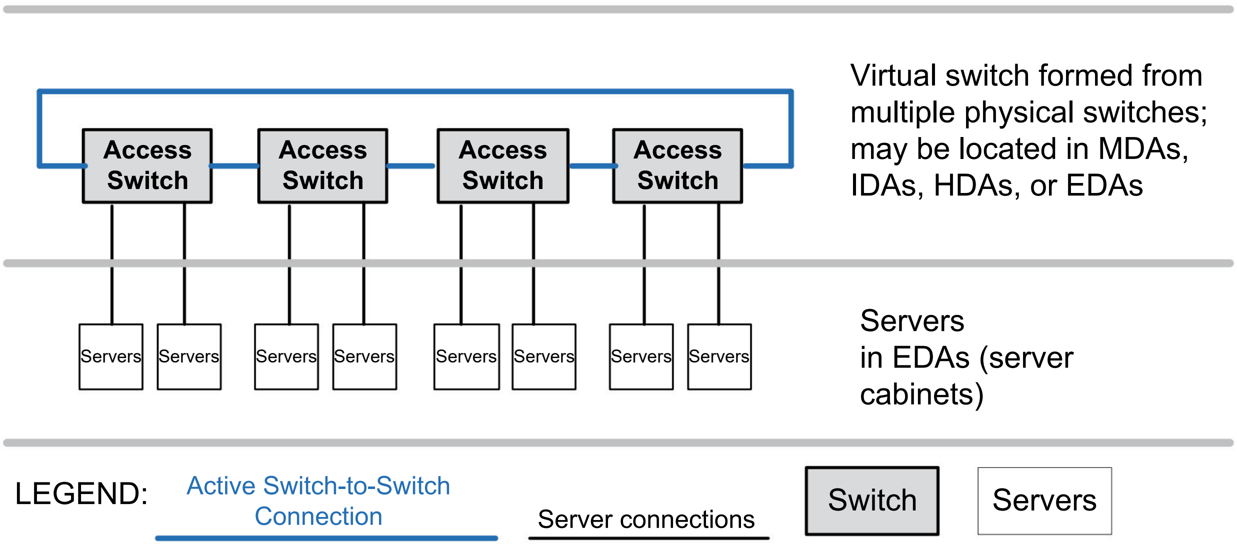


Figure 33: Virtual switch example

This architecture is similar to the centralized switch architecture except the centralized switch is implemented using multiple switches interconnected to form a single large virtual switch. The switches may be connected using stacking cables (cables used to interconnect stackable switches [a switch that can operate either alone as an independent switch or joined with other stackable switches to operate as a single larger switch]), high-speed Ethernet connections, or other scheme.

Each server may be connected to multiple virtual switches for redundancy.

This architecture may be non-blocking if the virtual switch backplane bandwidth is greater than or equal to the total bandwidth of server connections. Latency between switches within a virtual switch may be higher than that for other architectures if the virtual switch is composed of many daisy-chained switches.

As with the centralized switch architecture, this architecture does not scale well unless a fat-tree or full-mesh is implemented between virtual switches.

The switches may be located in any distributor (MDA, IDA, HDA) or in the EDAs.

Cabling for the virtual switch architecture should follow the ANSI/TIA-942-B cabling scheme. It can use the optional HDA-to-HDA backbone cabling if the access switches are located in the HDAs. Additionally, cabling between equipment in EDAs may be used if the access switches are located in the EDAs. If direct attach cabling is used, it should be no greater than 7 m (23 ft) and should be between cabinets/racks in the same row. This direct attach cabling should be routed in cable management or accessible pathways and not interfere with fixed cabling.

See figure 34 for an example of cabling supporting virtual switch fabric architecture.

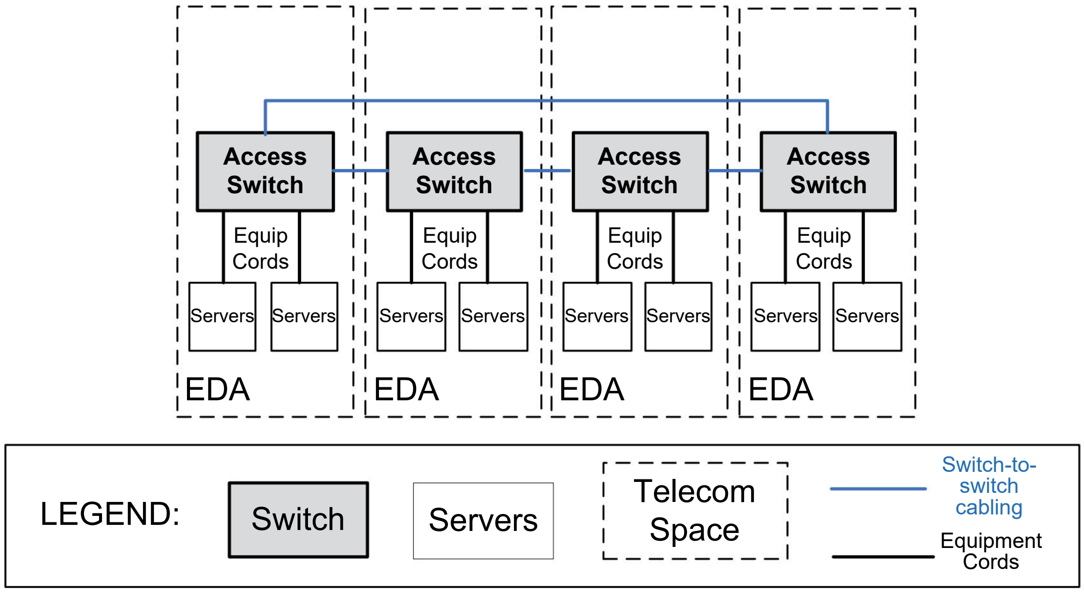


Figure 34: Example of cabling for fabric virtual switch architecture

ANNEX I (INFORMATIVE) BIBLIOGRAPHY

This annex is informative only and is not part of this Standard.

This annex contains information on the documents that are related to or have been referenced in this document. Many of the documents are in print and are distributed and maintained by national or international standards organizations. These documents can be obtained through contact with the associated standards body or designated representatives. The applicable electrical code in the United States is the National Electrical Code.

- ANSI/IEEE C2-2017, *National Electrical Safety Code®*
- ASHRAE, *Best Practices for Datacom Facility Energy Efficiency*, Second Edition (2009)
- ASHRAE, *Design Considerations for Data and Communications Equipment Centers*, Second Edition (2009)
- ASHRAE, T*hermal Guidelines for Data Processing Environments*, Fourth Edition, 2015
- ASTM B539-02 2013, *Standard Test Methods for Measuring Resistance of Electrical Connections (Static Contacts)*
- ANSI/BICSI 002-2014, *Data Center Design and Implementation Best Practices*
- BICSI *Telecommunications Distribution Methods Manual (TDMM), 13th Edition*, 2014
- BICSI *Information Technology Systems Installation Methods Manual (ITSIMM), 7th Edition*, 2017
- BICSI *Outside Plant Design Reference Manual (OSPDRM), 5th Edition*, 2010
- European Commission, 2017 Best Practices for EU Code of Conduct on Data Centres, Version 8.1.0 (2017);
- European Commission, European Code of Conduct on Data Centre Energy Efficiency, Introductory guide for applications 2016, Version 3.1.2
- Federal Communications Commission (FCC) Washington D.C., "*The Code of Federal Regulations, FCC 47 CFR 68*"
- Federal Telecommunications Recommendation 1090-1997*, Commercial Building Telecommunications Cabling Standard,* by National Communications System (NCS)
- IBC, *International Building Code, 2015 Edition*
- IEEE Std. 142*, Recommended Practice for Grounding of Industrial and Commercial Power Systems*
- IEEE Std. 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*
- IEEE Std. 1100, *Recommended Practice for Powering and Grounding Electronic Equipment*
- ANSI/IEEE 802.3-2015, *IEEE Standard for Ethernet*

- IEEE Standard 518-1982, *Guide for the installation of electrical equipment to minimize electrical noise to controllers of external sources*
- IFMA – *International Facility Management Association - Ergonomics for Facility Managers*, June 2000
- NFPA 72,*National Fire Alarm Code, 2016*
- NFPA 101 *Life Safety Code®, 2015*
- NFPA 2001, *Standard on clean agent fire extinguishing systems, 2015 Edition*
- NFPA 780-2017, *Standard for the Installation of Lightning Protection Systems* - See more at: http://catalog.nfpa.org/NFPA-780-Standard-for-the-Installation-of-Lightning-Protection-Systems
- NEMA VE 2-2013, *Cable Tray Installation Guidelines*
- ANSI/TIA-4994-2015 - *Standard for Sustainable Information Communications Technology*
- TIA TSB-162-A:2013 – *Telecommunications Cabling Guidelines for Wireless Access Points*
- TIA TSB-184-A:2016 – *Guidelines for Supporting Power Delivery over Balanced Twisted-Pair Cabling*, 2016
- TIA TSB-5018:2016 – *Structured Cabling Infrastructure Guidelines for Support of Distributed Antenna Systems*
- TIA TSB-5019-2015, *High Performance Structured Cabling Use Cases for Data Centers and Other Premises*
- TIA TSB-5046-2016 - *Standard Process for Sustainable Information Communications Technology Manufacturers*
- UL 444/CSA-C22.2 No. 214-08, *Communications Cables*

The organizations listed below can be contacted to obtain reference information.

ANSI
American National Standards Institute (ANSI)
25 West 43rd Street, 4th floor.
New York, NY 10032
USA
(212) 642-4900
www.ansi.org

ASHRAE
American Society of Heating, Refrigeration and Air conditioning Engineers (ASHRAE)
1791 Tullie Circle, NE
Atlanta, GA 30329
1-800-527-4723
(404) 636-8400
www.ashrae.org

ASTM
American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959
USA
(610) 832-9500
www.astm.org

BICSI
8610 Hidden River Parkway
Tampa, FL 33637-1000
USA
(800) 242-7405
www.bicsi.org

CSA
Canadian Standards Association International (CSA)
178 Rexdale Blvd.
Etobicoke, (Toronto), Ontario
Canada M9W 1R3
(416) 747-4000
www.csa-international.org

FCC
Federal Communications Commission (FCC)
Washington, DC 20554
USA
(301) 725-1585
www.fcc.org

NCS
Federal and Military Specifications
National Communications System (NCS)
Technology and Standards Division
701 South Court House Road Arlington, VA 22204-2198
USA
(703) 607-6200
www.ncs.gov

ICC/IBC
International Code Council (ICC)
International Building Code (IBC)
5203 Leesburg Pike, Suite 600
Falls Church, VA 22041
703-931-4533
www.iccsafe.org

IEC
International Electrotechnical Commission (IEC)
Sales Department
PO Box 131
3 rue de Varembe
1211 Geneva 20
Switzerland
+41 22 919 02 11
www.iec.ch

IEEE
The Institute of Electrical and Electronic Engineers, Inc (IEEE)
3 Park Avenue, 17th Floor
New York, NY 10016-5997 USA
(212) 419 7900
www.ieee.org

IPC
The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Rd.
Northbrook, IL 60062-6135
USA
(847) 509-9700
www.ipc.org

ISO
International Organization for Standardization (ISO)
Chemin de Blandonnet 8
CP 401
1214 Vernier, Geneva
Switzerland
+41 22 74 901 11
www.iso.ch

NEMA
National Electrical Manufacturers Association (NEMA)
1300 N. 17th Street, Suite 1847
Rosslyn, VA 22209
USA
(703) 841-3200
www.nema.org

NFPA
National Fire Protection Association (NFPA)
Batterymarch Park
Quincy, MA 02269-9101
USA
(617) 770-3000
www.nfpa.org

Telcordia Technologies (formerly; Bellcore)
Telcordia Technologies Customer Service
8 Corporate Place Room 3C-183
Piscataway, NJ 08854-4157
USA
(800) 521-2673
www.telcordia.com

TIA
Telecommunications Industry Association (TIA)
1320 North Courthouse Road, Suite 200
Arlington, VA 22201USA
(703) 907-7700
www.tiaonline.org

UL
Underwriters Laboratories, Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096
USA
(847) 272-8800
www.ul.com

THE TELECOMMUNICATIONS INDUSTRY ASSOCIATION

TIA represents the global information and communications technology (ICT) industry through standards development, advocacy, tradeshows, business opportunities, market intelligence and world-wide environmental regulatory analysis. Since 1924, TIA has been enhancing the business environment for broadband, wireless, information technology, cable, satellite, and unified communications.

TIA members' products and services empower communications in every industry and market, including healthcare, education, security, public safety, transportation, government, the utilities. TIA is accredited by the American National Standards Institute (ANSI).

ADVANCING GLOBAL COMMUNICATIONS

TELECOMMUNICATIONS INDUSTRY ASSOCIATION
1320 N. Courthouse Road, Suite 200
Arlington VA, 22201, USA
+1.703.907.7700 MAIN
+1.703.907.7727 FAX