Product-Neutral Tendering of Hardware for the School Sector

Guidelines for Public IT Procurement
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1 Introduction

1.1   Scope and application of this guide

This guide provides an overview of the principles and criteria for the procurement of hardware for the school sector. The aim of the document is to provide contracting authorities with a reliable and comprehensible aid so that they can formulate their tenders for procuring hardware for the school sector in a product-neutral manner, i.e. without using protected brand names or naming specific manufacturers and with due consideration of current technical requirements. The emphasis is placed on the procurement of mobile terminals, network infrastructures and presentation technologies.

This guide focuses on listing technical criteria that can be used to describe and compare the various hardware solutions themselves, as well as the requirements for their operational environment and other features. However, it should be noted that the technical criteria listed are subject to constant changes and should be weighted differently depending on the planned area of application of the equipment to be purchased. The higher the requirements for the product, the higher the offer price will tend to be and the smaller the range of products on the market will be. This guide can therefore not replace professional considerations and weighting of the respective criteria according to specific needs.

This guide describes the technical performance criteria for supporting the procurement of mobile devices based on the Android, Chrome and Windows operating systems. Devices with other operating systems are not covered by the guide.

However, the authors of the guide would also like to support procurers in public administration by drawing their attention to sensitive criteria and requirements, i.e. those that may restrict the market, and to cost-related decisions. The symbols defined below are used for this purpose.

Symbol	Meaning
€	The requirement of criteria with this symbol can lead to cost increases and/or market restrictions.
!	This symbol indicates the correction of a widespread error or marks particularly important statements in the text.
Z	This symbol indicates whether criteria can be verified with certificates.

1.2   Product neutrality as a legal requirement

In public procurement law, there is an obligation to treat suppliers and products on offer equally. The legal basis requires a description of the item to be procured according to objective and non-discriminatory criteria, i.e. a product-neutral description of services (cf. section 97(2) GWB and Section 31(6) VgV for EU-wide award procedures, as well as Section 55(1) BHO and Section 2(2) UVgO for sub-threshold award procedures).[1] Certain product designations or brand names may only be used in invitations to tender in justified exceptional cases if an adequately precise description using customary designations or general criteria is not possible.

However, product-neutral tenders can also be viewed as an opportunity. They guarantee fair and open competition, and they prevent technical pre-determinations and the resulting risk of lock-in effects. If procurement is carried out solely based on general, objective and technical criteria, the number of competing suppliers increases. This results in better options for selection and savings in purchasing processes, and market opportunities through supplier changes can be exploited without major difficulties.

In the context of public tenders, the contracting authority is also required to establish criteria for the product to be procured that allow for a comparison between different offers, thereby enabling sufficient differentiation between them. A contracting authority is free to decide which criteria it will use to select the goods or services to be procured, but the award criteria must be needs-based, product-neutral and transparent.

Particularly in the area of IT product procurement, however, a product-neutral tender is by no means an easy task and is often associated with major uncertainties for the public agencies concerned. The technical complexity of the subject matter, the rapid sequence of product cycles and, above all, the difficulty of estimating and precisely describing how a system is to perform, while taking all technical requirements into account, present public procurers with significant challenges.

This is precisely where this guide comes in, by providing compact assistance aimed at supporting compliance with the legal requirements in the formulation of technical specifications, thereby ensuring fair competition. The guide identifies and explains current technical standards that enable a description based on general, factual characteristics. In this context, the use of generally recognised benchmark procedures as an essential component of a product-neutral performance description is also considered.

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1   This principle is also clearly formulated in Article 42(4) of Directive 2014/24/EU of 26 February 2014: Unless it is warranted by the subject-matter of the contract, technical specifications may not refer to a specific make or source, or to a particular process that characterises the goods or services provided by a given economic operator, or to trademarks, patents, types or a specific origin or production if this favours or excludes certain companies or certain products.

2 Hardware as an object of procurement in the school sector

2.1   Benchmarks for evaluating the object of procurement

Benchmarks can be used to compare the performance of (mobile) terminals. A benchmark is a procedure used to compare similar products in the tendering process.

In the Bitkom guide, "Product-Neutral Tendering for Notebooks", performance requirements and battery life for two mobility classes (simple mobility, high mobility) are compared in chapter 3 (User profiles as a reflection of the workplace) based on benchmark procedures.[2] The suggestions can be transferred to the procurement of mobile devices (clamshell, convertible, detachable) in the school sector. We recommend using the values of the first mobility class (simple mobility) for primary level devices. The evaluation of devices for secondary levels I and II as well as teacher devices should be oriented towards the second mobility class (high mobility).

For the tablet device class, battery life is sufficient as a benchmark. This should cover at least one teaching day. The runtime can basically be differentiated according to the type of use (internet use, music playback, video playback, etc.). A minimum runtime of 10 hours with internet use (WLAN) is suggested as a benchmark for tablets

2.2   Commercial procurement models

Hardware can be procured by renting, buying or leasing it. In contrast to renting, leasing usually entitles the procurer to a purchase option for the leased item at the end of the contractual useful life. The approach selected by the procurer depends not least on whether it has a one-off budget or a budget covering several years.

Generally, one of the above-mentioned procurement models must be chosen in advance of the procurement measure in the context of an economic feasibility study. At the same time, it must also be decided whether hardware and operating system are to be procured from one source on a uniform contractual basis (bundling) or from different suppliers. Software manufacturers sometimes offer special licensing models for software intended for use in public administration.

A not insignificant consequence of the choice of procurement model relates to VAT. When renting, the VAT on the respective rental instalments accrues and must be paid together with the rental instalments. When purchasing, the entire VAT is incurred upon delivery (= transfer of the equipment to the client). The entire VAT is also incurred on delivery of the device if, according to the contract, ownership of the device is only to be transferred after payment of several instalments. If transfer of ownership in the case of a hire purchase depends on the exercise of an

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2   Vgl.: ↗ **https://www.itk-beschaffung.de/Leitf%C3%A4den/Notebooks**

option to purchase, VAT is payable on the entire price of the equipment when the option is exercised under the contract. If rental instalments have already been paid before exercising the option, the VAT payments incurred on them must be reversed if the rental instalments are offset against the purchase price. When leasing, VAT is incurred at the time when, according to the tax regulations, the leased equipment is assigned to the client.[3]

	Commercial models		
	Hardware and software from different suppliers	Bundling	Financing (Rental/Leasing)
Hardware	Purchase	Purchase	Rental or leasing
Operating system	Purchase and licensing (note licensing model)	Purchase and licensing (note licensing model)	Rental or leasing (note licensing model)
Costs for hardware service (e.g. repair, maintenance)	Borne by the client	Borne by the client	Fee covers services
Kosten für Software-Service (z. B. Bereitstellen und Einspielen von Updates)	Borne by the client	Borne by the client	Fee covers services
Eigentum von Hardware	Client	Client	Client

2.3   Services

The supplier's service portfolio does not need to be limited to the delivery of hardware and software but can also include other services related to the delivery item. For instance, it would be conceivable to offer to maintain and keep the delivered hardware and any software supplied up to date on the basis of a separate service contract or via a warranty extension. Furthermore, additional services, such as troubleshooting or hotline services can be contracted in addition to the pure hardware or software procurement.

If necessary, the corresponding support should be agreed together with the specification of response times/repair times.

Standard market offers differ according to:
- Duration of the contract
- Response times (time between fault report and first response from support)
- Restoration time (time between fault report and restoration of the system to operational readiness)
- Spare parts logistics
- Additional technical services offered (billing based on hourly rates and travel expenses).

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3   Cf. the statements of the tax authorities in section 3.5 para. 5 and 6 of the Value Added Tax Application Decree (UStAE) on these value added tax consequences.

Requirements can be based on need:

- 3, 4 or 5 years' on-site service
- On-site service with a response time of x hours. A response time of one hour (can also be an auto-response) within normal office hours (e.g. 8 a.m. to 5 p.m., although in the school sector it is usually sufficient to limit the response time to the period from 8 a.m. to 2 p.m.). Otherwise next working day.
- On-site service with a restoration time of x hours (type and scope depend on the purpose of use. Lower surcharge for restoration time of two working days, shorter times are possible but affect pricing).
- Availability of the German-speaking hotline x hours y days a week.
- Spare parts delivery without replacement by the service technician.
- Spare part storage at the customer's premises.
- After a replacement data carrier has been sent, the client should be allowed to destroy defective data carriers without returning them (depending on security requirements).

In the procurement of high-availability or security-relevant solutions, individual agreements can be made. In this case, a trade-off must be made between the urgency of the requirements and the resulting costs.

For the purchase of hardware, for example, the following additional specifications can be stipulated if necessary:

- Maximum delivery time
- Free delivery
- Delivery abroad
- Delivery to different locations
- Delivery to individual rooms
- Pre-installation of the operating system to be included in the delivery
- Pre-installation of additional software
- Creation of backup copies of the operating system to be supplied.

3 Procurement of terminal equipment

3.1   User profiles

The education system in Germany has five levels. The five levels are primary, lower secondary and upper secondary, tertiary and quaternary, which predominantly includes further education, for example from vocational providers or the adult education centres.

Example applications in the school sector include:

Access to digital content (e.g. via web browser)

Video conferencing / remote access for learning

Web applications & productivity tools

Programming & coding

Creation of digital content

Data analysis

Simulation & modelling

Artificial intelligence (AI) & machine learning
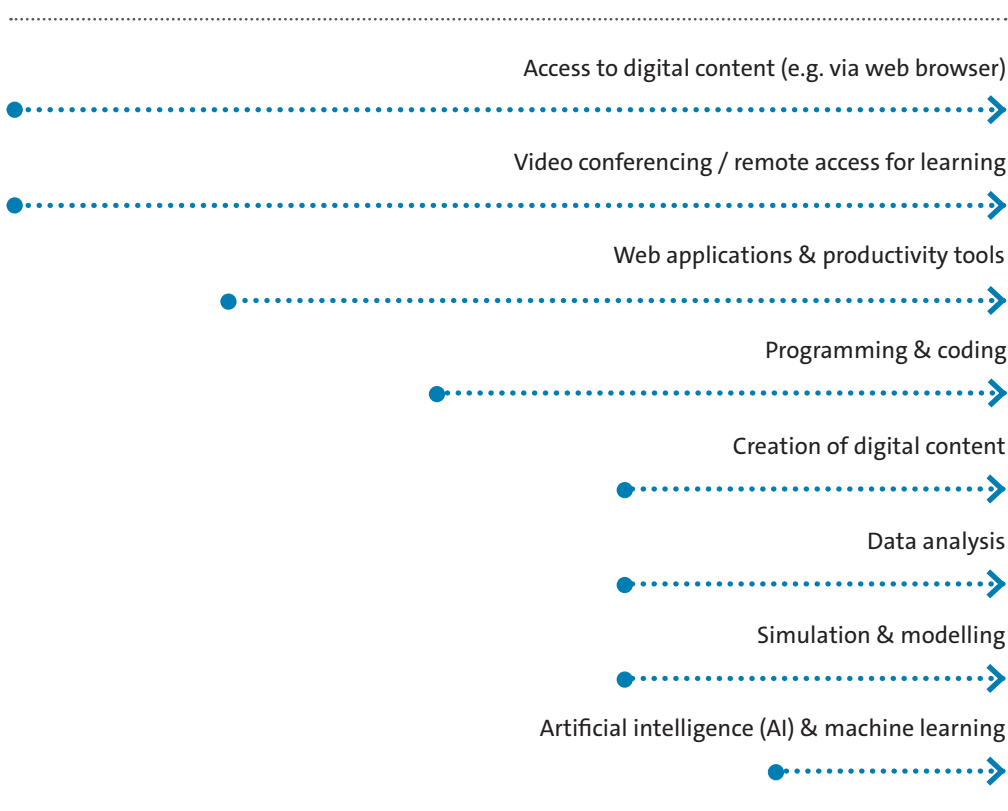
Figure 1: Applications in the school sector

3.1.1   Primary

Applications: Access to digital media and platforms such as web browsers, video playback, office applications, video conferencing and web applications
Device classes: Clamshell, Convertible, Detachable, Tablet

3.1.2   Secondary I and secondary II

Applications: as described in 3.1.1 + web applications and production tools to create, analyse and process content, creation of digital content (e.g. teaching and working materials, papers/presentations, image and video editing, etc.), programming and coding
Equipment classes: as described in 3.1.1

3.1.3 Teachers' and scientific applications

Application: as described in 3.1.2 + simulation and modelling, scientific applications such as artificial intelligence and machine learning
Device classes: as described in 3.1.1 + mobile workstation

3.2 Device classes

In this guide, we distinguish between the device classes:
- **Tablets (with/without keyboard)**
- **Notebooks/convertibles/2 in 1**
- **Desktop PCs**

Definition of form factors:

- **Clamshell** = Standard notebook/laptop - No tablet functionality (max. touch input - no pen input/display can be folded down max. 180 degrees)
- **Convertible** = Notebook with tablet function through 360-degree foldable display - touch input and mostly pen capable - keyboard not detachable
- **Detachable** = Tablet with (optional) dockable keyboard via integrated connectors (not Bluetooth) - touch input and pen capable
- **Tablet** = Tablet (fully functional without keyboard)

Note: Other terms used on the market:

- "2in1" can be equated with a convertible or detachable, depending on the specification.
- "Hybrid" generally describes devices that have both notebook and tablet functionalities
- "Chromebooks" are mobile devices with the ChromeOS operating system in the above-mentioned form factors
- "Booklet" refers to dual-touchscreen devices without a physical keyboard
- "Tablet PC" is synonymous with detachable

Side note - Mobile devices with touchscreen input options

There are three different ways to interact with a mobile device using a modern touchscreen:
- Finger input: Touching the screen with the fingertip is simple and intuitive, but imprecise.
- Pen input (passive stylus): Works similarly to using it with a finger. Since passive pens usually have blunt tips.
- Pen input (active pen): These pens are pressure sensitive and allow the user to draw fine lines and increase accuracy. Active pens can be used to reinforce handwriting instruction for younger students. Older pupils can write complex texts and formulas as well as draw graphics. Sensitive pens (S-Pen) are classified as active pens.

Unlike previous pens, active pens allow users to draw, write, highlight, annotate and rest their hands on the screen for a natural writing experience.

Key benefits of active pens include:
- Creativity: Pens give users more space for interactive, creative and stimulating learning experiences and facilitate non-linear thinking at all ages.
- Flexibility: Pens give users the flexibility to choose the best tool for the task at hand, be it a pen, fingers or keyboard.

The pen is a creativity tool. The keyboard is a productivity tool. Sometimes you need one, and sometimes you need both.

3.3 Technical criteria and requirements

3.3.1 Clamshell

User profile	Primary level
Examples of applications	- Access to and sharing of digital content - Video conferencing/remote access to learning - Web applications & productivity tools - Basic functions: Handwriting

No.	Criterion	Requirements	Suitable as	Remarks/explanations
1	Display resolution	- 1,366 × 768 pixels (HD) or - 1,920 × 1080 pixels (Full HD)	Minimum requirement	Higher values are available on the market. Market standard for screen sizes above 12.5 inches. As a rule, screen sizes are reduced with higher resolutions. Adjustments to the font and symbol sizes may be possible in the operating system.
		- Larger than Full HD	Evaluation criterion	Recommendation: 13" - 15"/For CAD/CAM: 15 – 17"
2	Antireflection coating	- Non-glare	Evaluation criterion	Adherence to non-reflective display with touch functionality leads to market restrictions. €
3	Processor type (CPU)	- x86 architecture	Minimum requirement	
		- Multi-Core	Minimum requirement	

No.	Criterion	Requirements	Suitable as	Remarks/explanations
4	Working memory (RAM)	▪ 4 GB	Minimum requirement	
		▪ More than 4 GB	Evaluation criterion	
		▪ Upgradability	Evaluation criterion	Upgrading of the RAM, especially for small and flat notebooks, is no longer common in the market, but can be used as an evaluation criterion.
5	Mass storage	▪ 128 GB SSD	Minimum requirement	An increase in the mass storage offers itself as an evaluation criterion.
6	Optical drives	▪ Internal	Evaluation criterion	Internal optical drives are no longer state of the art.
7	Ethernet	▪ RJ 45 Ethernet 10/100/1000 Mbit, can be achieved with adapter	Minimum requirement	Small and flat notebooks in particular often do not have an RJ-45 interface due to their design; a corresponding adapter can therefore be considered equivalent.
		▪ WOL / PXE 2.x	Minimum requirement	WOL should also be possible from the energy-saving states S4 and S5
8	WLAN	▪ WLAN according to IEEE 802.11n (Dual Band 2.4 and 5 GHz)	Minimum requirement	The WLAN standard IEEE 802.11 (AC A, B, G, N) must be supported.
		▪ WLAN according to 802.11ax (Wi-Fi 6)	Evaluation criterion	**€**
9	Bluetooth	▪ BT 5.0	Minimum requirement	The WLAN/Bluetooth modules are usually combo modules.
10	WWAN	▪ 4G LTE (integrated), data transmission rate ≥ ▪ 100 Mbit/s for download and ≥ 50 Mbit/s ▪ for upload	Evaluation criterion	Higher data transmission rates are available on the market. **€**
11	USB	▪ 2 × USB 3.x, of which min. 1 × type A	Minimum requirement	Please note that if one of the USB type C interfaces is also used to charge the notebook, it is occupied during the charging process and cannot be used to connect other peripherals.
12	Displayausgang	▪ 1 Digitalanschluss für Bildschirme	Minimum requirement	The exact type should be specified (e.g. HDMI, Mini HDMI, USB-C, Display Port, Mini DisplayPort), adapters should be allowed to ensure broad competition. The VGA port is no longer state of the art.
13	Audio	▪ Audio In & Audio Out	Minimum requirement	Fulfilment also by providing a combined interface
14	Keyboard	▪ German keyboard layout	Minimum requirement	Separate numeric keypad common on 15-inch models and above.
		▪ Backlit keyboard	Evaluation criterion	
15	Front camera	▪ 720p HD resolution	Minimum requirement	
16	Biometric sensor	▪ Fingerprint Sensor	Evaluation criterion	
		▪ Infrared webcam	Evaluation criterion	

No.	Criterion	Requirements	Suitable as	Remarks/explanations
17	Loudspeaker	▪ Stereo	Minimum requirement	
	Microphone	▪ Mono	Minimum requirement	
18	Touchpad	▪ Two-button function	Minimum requirement	
19	Touchpad	▪ OEM licence (e.g. Windows, ChromeOS, Linux) or without operating system (operating system must be procured separately in this case).	Minimum requirement	Supplementary information on Windows 10 Pro Education: The operating system is based on the commercial version of Windows 10 Pro and offers important management control options that are needed in schools. Windows 10 Pro Education is basically a variant of Windows Pro with default settings specifically for educational institutions, including the removal of Cortana. These default settings disable tips, tricks and suggestions, as well as Microsoft Store suggestions. Windows 10 Pro Education is available on new devices and can be purchased as a discounted licence for general education institutions through OEM partners. These discounted licences are sometimes referred to as National Academic or Shape the Future.
20	Operating system	▪ Integrated into CPU ▪ DirectX 12 capable	Minimum requirement	The graphics unit is located in the CPU/APU.
		▪ Discrete ▪ DirectX 12-capable	Evaluation criterion	The graphics unit is located as an independent unit on the motherboard. For mobile workstations, e.g. CAD/CAM workstations. **€**

3.3.2 Convertible

User profile	Primary level
Examples of applications	▪ Access to and sharing of digital content ▪ Video conferencing/remote access to learning ▪ Web applications & productivity tools ▪ Basic functions: Handwriting

No.	Criterion	Requirements	Suitable as	Remarks/explanations
1	Display resolution	▪ 1,366 × 768 pixels (HD) or ▪ 1,920 × 1080 pixels (Full HD)	Minimum requirement	Higher values are available on the market. Market standard for screen sizes above 12.5 inches. As a rule, screen sizes are reduced with higher resolutions. Adjustments to the font and symbol sizes may be possible in the operating system.
		▪ Larger than Full HD	Evaluation criterion	Recommendation: 13" - 15"/For CAD/CAM: 15 – 17"

No.	Criterion	Requirements	Suitable as	Remarks/explanations
2	Antireflection coating	▪ Non-glare	Evaluation criterion	Adherence to non-reflective display with touch functionality leads to market restrictions. €
3	Processor type (CPU)	▪ x86 architecture	Minimum requirement	
		▪ Multi-core	Minimum requirement	
4	Working memory (RAM)	▪ 4 GB	Minimum requirement	
		▪ More than 4 GB	Evaluation criterion	
		▪ Upgradability	Evaluation criterion	Upgrading of the RAM, especially for small and flat notebooks, is no longer common in the market, but can be used as an evaluation criterion.
5	Mass storage	▪ 128 GB SSD	Minimum requirement	An increase in the mass storage offers itself as an evaluation criterion.
6	Optical drives	▪ Internal	Evaluation criterion	Internal optical drives are no longer state of the art.
7	Ethernet	▪ RJ 45 Ethernet 10/100/1000 Mbit, can be achieved with adapter	Minimum requirement	Small and flat notebooks in particular often do not have an RJ-45 interface due to their design; a corresponding adapter can therefore be considered equivalent.
		▪ WOL / PXE 2.x	Minimum requirement	WOL should also be possible from the energy-saving states S4 and S5
8	WLAN	▪ WLAN according to IEEE 802.11n (Dual Band 2.4 and 5 GHz)	Minimum requirement	The WLAN standard IEEE 802.11 (AC A, B, G, N) must be supported.
		▪ WLAN according to 802.11ax (Wi-Fi 6)	Evaluation criterion	€
9	Bluetooth	▪ BT 5.0	Minimum requirement	The WLAN/Bluetooth modules are usually combo modules.
10	WWAN	▪ 4G LTE (integrated), data transmission rate ≥ 100 Mbit/s for download and ≥ 50 Mbit/s for upload	Evaluation criterion	Higher data transmission rates are available on the market. €
11	USB	▪ 2 × USB 3.x, of which min. 1 × type A	Minimum requirement	Please note that if one of the USB type C interfaces is also used to charge the notebook, it is occupied during the charging process and cannot be used to connect other peripherals.
12	Display output	▪ 1 Digital connection for screens	Minimum requirement	The exact type should be specified (e.g. HDMI, Mini HDMI, USB-C, Display Port, Mini DisplayPort), adapters should be allowed to ensure broad competition. The VGA port is no longer state of the art.
13	Audio	▪ Audio In & Audio Out	Minimum requirement	Fulfilment also by providing a combined interface
14	Keyboard	▪ German keyboard layout	Minimum requirement	Separate numeric keypad common on 15-inch models and above.
		▪ Backlit keyboard	Evaluation criterion	

No.	Criterion	Requirements	Suitable as	Remarks/explanations
15	Front camera	• 720p HD resolution	Minimum requirement	
16	Biometric sensor	• Fingerprint Sensor	Evaluation criterion	
		• Infrared webcam	Evaluation criterion	
17	Loudspeaker	• Stereo	Minimum requirement	
	Microphone	• Mono	Minimum requirement	
18	Touchpad	• Two-button function	Minimum requirement	
19	Operating system	• OEM licence (e.g. Windows, ChromeOS, Linux) or without operating system (operating system must be procured separately in this case).	Minimum requirement	Supplementary information on Windows 10 Pro Education: The operating system is based on the commercial version of Windows 10 Pro and offers important management control options that are needed in schools. Windows 10 Pro Education is basically a variant of Windows Pro with default settings specifically for educational institutions, including the removal of Cortana. These default settings disable tips, tricks and suggestions, as well as Microsoft Store suggestions. Windows 10 Pro Education is available on new devices and can be purchased as a discounted licence for general education institutions through OEM partners. These discounted licences are sometimes referred to as National Academic or Shape the Future.
20	Graphics unit	• Integrated into CPU • DirectX 12 capable	Minimum requirement	The graphics unit is located in the CPU/APU.
		• Discrete • DirectX 12-capable	Evaluation criterion	The graphics unit is located as an independent unit on the motherboard. For mobile workstations, e.g. CAD/CAM workstations €
21	Pen input device	• Active pen	Evaluation criterion	

3.3.3   Detachable

User profile	Primary level
Examples of applications	• Access to and sharing of digital content • Video conferencing/remote access to learning • Web applications & productivity tools • Basic functions: Handwriting

No.	Criterion	Requirements	Suitable as	Remarks/explanations
1	Display resolution	• 1,366 × 768 pixels (HD) or • 1,920 × 1080 pixels (Full HD)	Minimum requirement	Higher values are available on the market. Market standard for screen sizes above 12.5 inches. As a rule, screen sizes are reduced with higher resolutions. Adjustments to the font and symbol sizes may be possible in the operating system.
		• Larger than Full HD	Evaluation criterion	Recommendation: 13” - 15”/For CAD/CAM: 15 – 17“
2	Antireflection coating	• Non-glare	Evaluation criterion	Adherence to non-reflective display with touch functionality leads to market restrictions. €
3	Processor type (CPU)	• x86 architecture	Minimum requirement	
		• Multi-core	Minimum requirement	
4	Working memory (RAM)	• 4 GB	Minimum requirement	
		• More than 4 GB	Evaluation criterion	
		• Upgradability	Evaluation criterion	Upgrading of the RAM, especially for small and flat notebooks, is no longer common in the market, but can be used as an evaluation criterion.
5	Mass storage	• 128 GB SSD	Minimum requirement	An increase in the mass storage offers itself as an evaluation criterion.
6	Optical drives	• Internal	Evaluation criterion	Internal optical drives are no longer state of the art.
7	Ethernet	• RJ 45 Ethernet 10/100/1000 Mbit, can be achieved with adapter	Minimum requirement	Small and flat notebooks in particular often do not have an RJ-45 interface due to their design; a corresponding adapter can therefore be considered equivalent.
		• WOL / PXE 2.x	Minimum requirement	WOL should also be possible from the energy-saving states S4 and S5
8	WLAN	• WLAN according to IEEE 802.11n (Dual Band 2.4 and 5 GHz)	Minimum requirement	The WLAN standard IEEE 802.11 (AC A, B, G, N) must be supported.
		• WLAN according to 802.11ax (Wi-Fi 6)	Evaluation criterion	€
9	Bluetooth	• BT 5.0	Minimum requirement	The WLAN/Bluetooth modules are usually combo modules.
10	WWAN	• 4G LTE (integrated), data transmission rate ≥ 100 Mbit/s for download and 50 Mbit/s for upload	Evaluation criterion	Higher data transmission rates are available on the market. €

No.	Criterion	Requirements	Suitable as	Remarks/explanations
11	USB	• 2 × USB 3.x, of which min. 1 × type A	Minimum requirement	Please note that if one of the USB type C interfaces is also used to charge the notebook, it is occupied during the charging process and cannot be used to connect other peripherals.
12	Display output	• 1 Digital connection for screens	Minimum requirement	The exact type should be specified (e.g. HDMI, Mini HDMI, USB-C, Display Port, Mini DisplayPort), adapters should be allowed to ensure broad competition. The VGA port is no longer state of the art.
13	Audio	• Audio In & Audio Out	Minimum requirement	Fulfilment also by providing a combined interface
14	Keyboard	• German keyboard layout	Minimum requirement	Separate numeric keypad common on 15-inch models and above.
		• Backlit keyboard	Evaluation criterion	
15	Front camera	• 720p HD resolution	Minimum requirement	
16	Biometric sensor	• Fingerprint Sensor	Evaluation criterion	
		• Infrared webcam	Evaluation criterion	
17	Loudspeaker	• Stereo	Minimum requirement	
	Microphone	• Mono	Minimum requirement	
18	Touchpad	• Two-button function	Minimum requirement	
19	Operating system	• OEM licence (e.g. Windows, ChromeOS, Linux) or without operating system (operating system must be procured separately in this case).	Minimum requirement	Additional information on Windows 10 Pro Education: The operating system is based on the commercial version of Windows 10 Pro and offers important management control options that are needed in schools. Windows 10 Pro Education is basically a variant of Windows Pro with default settings specifically for educational institutions, including the removal of Cortana. These default settings disable tips, tricks and suggestions, as well as Microsoft Store suggestions. Windows 10 Pro Education is available on new devices and can be purchased as a discounted licence for general education institutions through OEM partners. These discounted licences are sometimes referred to as National Academic or Shape the Future.
20	Graphics unit	• Integrated into CPU • DirectX 12 capable	Minimum requirement	The graphics unit is located in the CPU/APU.
		• Discrete • DirectX 12-capable	Evaluation criterion	The graphics unit is located as an independent unit on the motherboard. For mobile workstations, e.g. CAD/CAM workstations 💶
21	Pen input device	• Active pen	Evaluation criterion	

3.3.4 Tablets

User profile	Primary level
Examples of applications	▪ Access to and sharing of digital content ▪ Video conferencing/remote access for learning (Please note that web applications and apps do not always have the same scope and operating options as software applications for PCs) ▪ Web applications & productivity tools (please note that web applications and apps do not always have the same scope and operating capabilities as software applications for PCs) ▪ Basic functions: Handwriting

No.	Criterion	Requirement	Suitable as	Remarks
1	Weight	▪ Max. 1kg	Minimum requirement	Weight is understood as tablet incl. case (if available), without keyboard.
2	Operating system	▪ OEM licence (e.g. Windows, ChromeOS, Android) or without operating system (operating system must be procured separately in this case).	Minimum requirement	When selecting the operating system, attention must be paid to which software applications they are suitable for. If necessary, check availability of company-specific applications (web applications/desktop app/browser-based apps/mobile device management (MDM).
3	Processor type (CPU)	▪ x86/ Multi-core –Architecture, ARM	Minimum requirement	
4	RAM (Random Access Memory)	▪ Windows: 4 GB RAM ▪ ChromeOS: 3GB RAM ▪ Android: 3GB RAM	Minimum requirement	
		▪ Windows: More than 4GB RAM	Evaluation criterion	
5	Storage capacity	▪ 32/64 GB internal memory	Evaluation criterion	The memory of the terminal is expandable through the use of a micro-SD card or other external storage media, if applicable.
6	Comms / Wifi / LTE	▪ Wi-Fi 5 ac / Wi-Fi 6 (ax), Bluetooth 5	Evaluation criterion	
7	Display size	▪ min. 10.0 inch ▪ Display resolution min. 1280x 800 pixels	Minimum requirement	
8	Battery life	▪ 10 hours	Minimum criterion	The size of the battery and the conditions of use have a significant influence on the runtime.
9	Connections/ interfaces	USB Type-C connection ▪ Micro-SD compatible ▪ Front and rear camera	Evaluation criterion	Wired or wireless (e.g. Bluetooth) keyboard as optional accessory. Bluetooth) keyboard as optional accessory.
10	Touch display	▪ yes	Minimum criterion	The terminal has a pen input facility
11	Pen function	▪ yes	Evaluation criterion	The terminal has a pen input facility

No.	Criterion	Requirement	Suitable as	Remarks
12	Form factor/ device class	▪ Enclosure: MILT STD 810G-516.6 (drop test passed) or through use of a protective cover ▪ he terminal is compatible with a keyboard cover ▪ Optional protective cover	Evaluation criterion	When using a cover, the total weight increases significantly and the haptics of the system may be limited.
13	Access control	▪ yes	Minimum requirement	
14	Guarantees	▪ At least 3 years of guaranteed software updates from the manufacturer ▪ At least 3 years manufacturer's hardware warranty ▪ Min. 2 major OS upgrades within the life cycle	Evaluation criterion	
15	Security management	▪ Terminal has a trust zone ▪ The trust zone must consist of three core components: TIMA KeyStore, real-time kernel protection, attestation ▪ Provides security and management interfaces for terminal management ▪ Compatible with a keyboard cover	Evaluation criterion	

3.3.5   Desktop PCs

To assist public contracting authorities in formulating their tenders for the procurement of desktop PCs, a separate guideline is available at ↗ **https://www.itk-beschaffung.de**, which is updated at regular intervals.

3.3.6   General technical criteria and requirements

Docking functionality

The manufacturer designation for a docking station is not uniform. Depending on the manufacturer, designations such as port replicator, travel dock or mini dock are also used.

The connection to the docking station is either via a manufacturer-specific (proprietary) interface or via USB or USB-C (universal). The docking interface used largely determines the number and speed of the connections provided and whether or not the notebook can be charged via the docking station.

No.	Criterion	Requirements	Suitable as	remarks/explanations
1	Docking connection	• Proprietary or Universal (USB/USB-C)	Minimum requirement	
2	Docking functionality	• Charging function	Minimum requirement	
		• Mechanical theft protection of the docking station	Minimum requirement	Docking station has a device for attaching a cable lock
		• Mechanical anti-theft protection for docked notebook computer	Evaluation criterion	Option to lock the notebook to the docking station (depending on the manufacturer's product). €
		• WOL/PXE 2.x	Minimum requirement	WOL should also be possible from the energy-saving states S4 and S5
		• Use of a device- related MAC address- (MAC address pass-through)	Evaluation criterion	
3	Connections	• 2 digital connections for screens (can be used in parallel)	Minimum requirement	The exact type should be specified (e.g. HDMI, Mini HDMI, USB-C, Display Port, Mini DisplayPort), adapters should be allowed to ensure broad competition.
		• RJ45	Minimum requirement	
		• 4 × USB, including min. 2 × USB3.x and 2 × type A	Minimum requirement	
		• Audio In & Audio Out	Minimum requirement	Fulfilment also through provision of a combination interface, if necessary, splitter adapter to be enclosed
4	Power supply unit	• Power supply unit suitable for the docking station	Minimum requirement	An adequately dimensioned power supply unit must be included in the scope of delivery of the docking station.

Power supply

No.	Criterion	Requirements	Suitable as	Remarks/explanations
1	Weight of power supply unit and cable	• High mobility: max. 430 g • Medium & low mobility: No concrete recommendation, may be heavier than 430 g • Proprietary device port or USB-C	Minimum requirement	If the total length (socket to notebook) of cable and power supply is to be more than 1.80 m, the maximum total weight of power supply and cable must be increased. The weight depends on the performance of the power supply unit. Proprietary device connection depending on the manufacturer's product. €
2	Total length of cable and power supply unit (socket to notebook)	• 1.80 m	Minimum requirement	

No.	Criterion	Requirements	Suitable as	Remarks/explanations
3	Power	• With the office running, a battery with a charge level of 10 percent must be charged to a charge level of at least 90 percent of its capacity within 3 hours.	Minimum requirement	The charging times of the batteries depend on the power of the power supply unit and the capacity of the battery.
4	Battery interchangeability	• Replaceable with tools, if necessary, even with special tools	Evaluation criterion	As a rule, the enclosure of the notebook must be opened for this purpose.
		• Can be changed without tools	Evaluation criterion	The enclosure does not have to be opened. Also only available on the market to a limited extent.

3.4 End device security

Mobile terminals can become the target of cyber attacks, data theft and data misuse. Such attacks endanger the confidentiality, availability and integrity of the data processed and stored with the devices as well as the functionality of the devices themselves. Modern terminals can be equipped ex works with integrated security functions that can support compliance with security requirements. Data protection and data security can ultimately only be established through a combination of organisational measures, due diligence on the part of the device user and security functions inherent in the device.

No.	Criterion	Requirements	Suitable as	comments/explanations
1	Mechanical anti-theft protection	• Device for mounting a mechanical anti-theft device • Anchored in the inner notebook frame	Minimum requirement	Suitable locks etc. must be procured separately as accessories. May have an influence on the design/thickness/dimensions of the unit. For additional locking options, see docking functionality.

No.	Criterion	Requirements	Suitable as	comments/explanations
2	TPM	▪ TPM 1.2/2.0 ▪ If TPM is present: can be switched off in firmware ▪ (see also TCG PC Client Platform Firmware Profile 6.1). This type of deactivation must not be reversible by the operating system. or ▪ No TPM or irrevocably deactivated	Minimum requirement	TPM (Trusted platform module) is a feature that stores keys, passwords & digital certificates. For use with Windows 10, delivery of a TPM 2.0 is recommended. For use with Windows 7, delivery of a TPM 1.2 is recommended. For other use (virtualisation, Linux): Delivery without TPM or with deactivated TPM recommended. Reference to Microsoft webpage, as depending on the operating system and version, a limited range of functions is possible. Depending on the intended use, the possibility of upgrading and downgrading between TPM 1.2 and 2.0 may be required.
		▪ Pre-boot hard disk password option in firmware	Evaluation criterion	If configured accordingly, the hard disk can only be started after entering the password.
		▪ Password option for access to firmware (e.g. BIOS/UEFI)	Minimum requirement	Access to firmware with graded rights with firmware passwords. Depending on the user's internal security policy, an access password should be set during initial commissioning.
		▪ Individual Firmware settings	Evaluation criterion	The delivery state may include BIOS/ UEFI/coreboot settings specified in advance by the client.
		▪ Secure boot ("Secure Boot") to check the integrity of the hardware components ▪ Can be switched off in firmware	Minimum requirement	When operating with Windows 7, Secure Boot must be switched off. For Windows 7, please refer to the chapter "Operating Systems" of this guide.
3	Out-of-Band Management	▪ If available, delivered deactivated in the firmware; can only be activated with firmware password	Minimum requirement	Remote maintenance functions that can change the firmware and/or data independently of the operating system must be delivered deactivated, if they are available. Activation of the functions must be protected and must only be possible with a firmware password. When deactivated, the functions must neither establish nor accept network connections.
4	BIOS/UEFI/ coreboot tamper protection	▪ Detection of and protection against tampering, and reliable notification of the owner or user.	Minimum requirement	The systems must have mechanisms that prevent tampering with the firmware itself (e.g. by write protection) or detect tampering (e.g. by signature verification) and reliably notify the owner or user of any event of this kind.

No.	Criterion	Requirements	Suitable as	comments/explanations
5	Firmware, hardware	• Patch management exists as well as information on patch management for vulnerabilities in firmware and hardware	Minimum requirement	Firmware here refers to firmware that runs on or can affect the main processor (e.g. BIOS, UEFI, Coreboot) (e.g. Intel ME, AMD PSP). The bidder must provide detailed documentation on how vulnerabilities in hardware and firmware will be handled, including dependencies on third parties (e.g. suppliers). Anticipated deadlines for addressing vulnerabilities in firmware are part of this documentation.
		• After public disclosure of a critical vulnerability (CVSS 2.0 Base Score 7.0-10.0) of the firmware, it must be fixed immediately.	Minimum requirement	
6	Encryption	• Hardware-based drive encryption	Minimum requirement	Integrated hardware and firmware provide automated encryption of data (e.g. OPAL). No operating system support or separate software installation is required.
7	Interface protection	• Interfaces in BIOS/ UEFI/ coreboot can be disabled	Minimum requirement	e.g. Ethernet, USB, WLAN, WWAN, Bluetooth, camera, microphone, fingerprint sensor, etc.
8	Authentication of the user	• Possibilities of multifac-tor-authentication	Minimum requirement	e.g. smart card, fingerprint, other biometric features, etc.
9	Webcam covering	• Integrated or retrofitted physical webcam cover	Evaluation criterion	€
10	View protection	• Privacy filter (integrated or as an accessory)	Evaluation criterion	Solution depends on system manufacturer. €

4 Procurement of infrastructure

4.1   Technical criteria and requirements

4.1.1   Building infrastructure
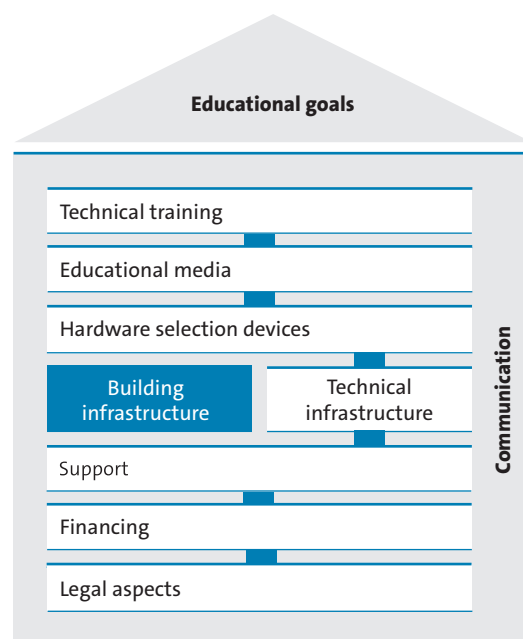
Figure 2: Participants: School authorities, municipalities, school management

Working with digital devices and tools in schools calls for in-depth planning for the provision and placement of data and power connections as well as information and communication networks. The IT infrastructure requires a supportive building infrastructure and a corresponding concept for the design of the premises at a school to assure learning scenarios for education in a digital world.

Schools have network areas with a high need for protection. This is why separation into an administrative network and a pedagogical network (pupil/instructional area) usually still takes place physically at schools. However, separation is also possible logically even with shared components by separating the networks at the school, e.g. by means of VLAN or VXLAN.[4]

Gemeinsame Richtlinien und ein Ausstattungskonzept für die Infrastruktur in den Schulgebäuden sind unerlässlich bei der Planung des Gesamtkonzeptes einer Schule. Obwohl die Gesamtraumausstattung eine bedeutende Rolle bei der Umsetzung innovativer Unterrichtsplanung spielt, werden hier ausschließlich die technischen Aspekte erläutert.

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4   Further explanations are provided in the glossary.

Technical equipment: Connections

The planning of the interior equipment must include the provision of the necessary power supply and the requisite number of connections for the use of both stationary and mobile devices in the classroom. The costs for the power supply must be included in the building strategy, if necessary. Appropriate placement of the connections and load on the power supply must be considered. Wired connections do not replace WLAN, but are necessary for the use of access points, for example.

Cabling of at least Cat. 5e or better should be used. The table below is only one possible example of this type of connection strategy and serves to illustrate the complexity of a school concept. Basically, the connection strategy depends on the actual size of the respective classrooms. In addition, the building structure must be taken into account in each individual case (new construction, renovation, existing building). In the following table, a comparatively high number of connections (10) is therefore suggested with regard to the equipment of the classrooms. This recommendation applies especially to new buildings and refurbishments. The respective school type must also be taken into account; for example, a higher number of connections is recommended for vocational schools.

Example of a connection concept[5] for the whole school[6]

Number of connections			
Room type	**Data connections**	**Power sockets**	**Other**
Teaching	10 6 in the front, 2 at the storage location for mobile terminals, 2 ceiling in the front: Telephone and PC whiteboard, projector ceiling: Access point	10 connection possibilities pupil connections[A]: 2 additional ones in new buildings. 6 at teacher's workstation[B] circuits: 2 (1x pupil connections, 1 x teacher workstation)	Depending on the building structure and school type. The recommendations refer to new buildings or refurbishments.
EDP premises	8 connections for central components and one additional connection per pupil. 2 ceiling for access point.	10 connections for central components and 2 additional connections per pupil workstation.	Standard EDP room = 20 pupils; distribution cabinet not in the room. With 20 pupils, this means 50 connections for power and 28 for data
Teachers' room	10 connections for PCs and telephone and 2 for access point	Power connections for 10 PC workstations plus kitchen appliances/presentation equipment	Exceptions possible in consultation with DIP/IT-6 (size of the staff room/number of teachers).
Head teacher/administration	per workstation 34 2 ceiling for access point	Power connections per PC workstation plus kitchen equipment	

5 Two connections result in one double socket each

6 from an example out of the city of Nuremberg

Number of connections

Room type	Data connections	Power sockets	Other
Preparation/ silent rooms	6 connections for PCs and telephone plus 2 for access point	Power connections for 5 PC workstations plus kitchen equipment	
Youth welfare staff at schools	per workstation 3[C]	Power connections per PC workstation plus kitchen equipment	
Caretaker	per workstation 3[C]	9	Mobilfunk (one number)
Study area, parents' consulting room, library, school annexes (first aid, …)	per workstation 3[C]	Power connections per PC workstation plus kitchen equipment plus other equipment such as defibrillator	
Assembly hall/ refectory/ auditorium/ control room (stage equipment)	8 plus 2 per access point after survey	At least one socket per data connection + connections according to technical planning for event technology	
Subject classrooms (chemistry, physics, etc.)	Individual solutions, in consultation with IT-6 or H/E	Individual solutions, in consultation with IT-6 or H/E	
Technical room air-conditioning, ventilation, heating, central fire alarm system	4	At least one socket per data connection + connections according to HVAC planning	
Staircase and corridors	If necessary, 2 per access point according to survey in the corridor areas	Standard	

A Private or mobile devices approved for use by pupils: Max. number of 30, of which simultaneously connected to the power supply max. 15. Preference should be given to multichargers/charging stations for the mobile devices.

B Presentation technology such as projector, digital boards, document camera, 1 PC, charging unit for mobile urban devices. Devices, 6 power connections in total.

C Rounded up to an even number if necessary.

Example of classroom power outlets[7]

The equipping of the individual rooms in the school building can be done on the basis of the pedagogical concept and the media development plan. The size of the room, the building structure and the type of school play a role here.

7   from an example out of the city of Nuremberg

Number of connections		
Room type	Data	Power
Teaching	10 4 front 4 rear, 2 ceiling Front: Telephone and PC Interactive whiteboard Projector In the back: IT administration Ceiling: Access point	20: Connection options Pupil connections Teacher workstation Circuits: 2 (1x pupil connections, 1x teacher workstation)

- Mobile terminals approved for pupil use: Min. number of 30, of which simultaneously connected to the power supply max. 15
- Presentation technology such as projector, digital board, document camera, 1 PC, charging unit for mobile urban equipment

Figure 3: Example of a room equipment concept including connections

Network structure

The planning of the logical network structure is to be coordinated with the users/operators and corresponding offices. Basically, the data network is divided into three structural areas:

Primary or core area:
Represents the cross-building networking between buildings on a site (campus area). If there is only one building, the primary area consists only of the central main distributor.

Secondary or distribution area:

Comprises the network connections between the central main distributor or main building distributor (GHVt) and the area distributors (BVt). If there are no area distributors, the secondary area is omitted.

Tertiary or access area:

Covers the connections between the area distributors or the main distributor (if there are no area distributors) and the network end points (connection boxes at the workspace).

The buildings must be networked across the entire area. Protection must be provided against network failures.
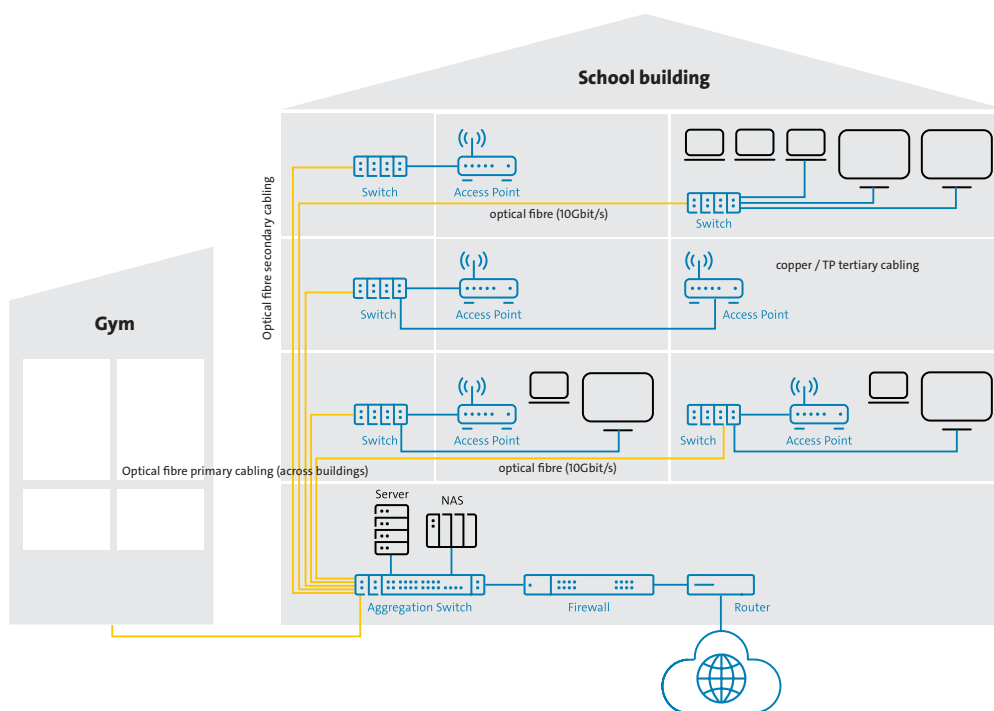
Figure 4: Building infrastructure

CHECKLIST: BUILDING INFRASTRUCTURE	**?**

☐ Are there common guidelines and an equipment concept for the infrastructure in the school building?
☐ Does the space concept offer flexibility and security for the design of lessons?
☐ Have any advances in technology been considered as far as possible?
☐ Is there a comprehensive plan for the connections needed in the school building?
☐ Have the costs of cabling and power connections been considered?

4.1.2   Technical infrastructure
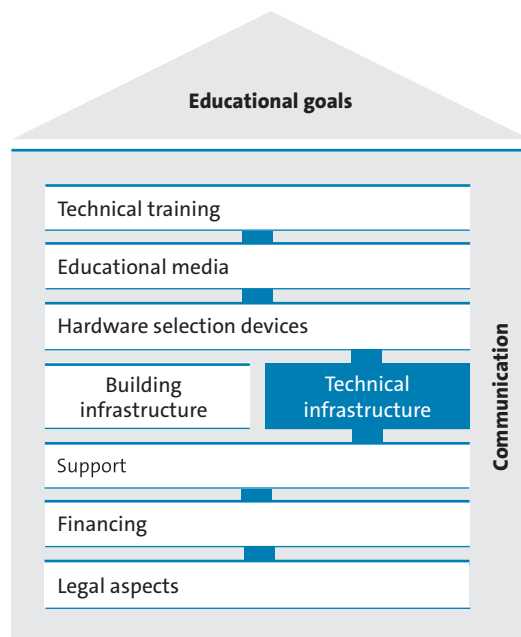
Figure 5: Participants: School authorities, municipalities, school management

In addition to the passive technical infrastructures described in the cornerstone "Building infrastructure" (structured cabling, etc.), a professional active IT infrastructure is needed for the use of digital content in lessons. In addition to the network and the presentation media, this also includes a school server and/or cloud system.

A successfully implemented IT infrastructure requires a series of sequential decisions and implemented steps:
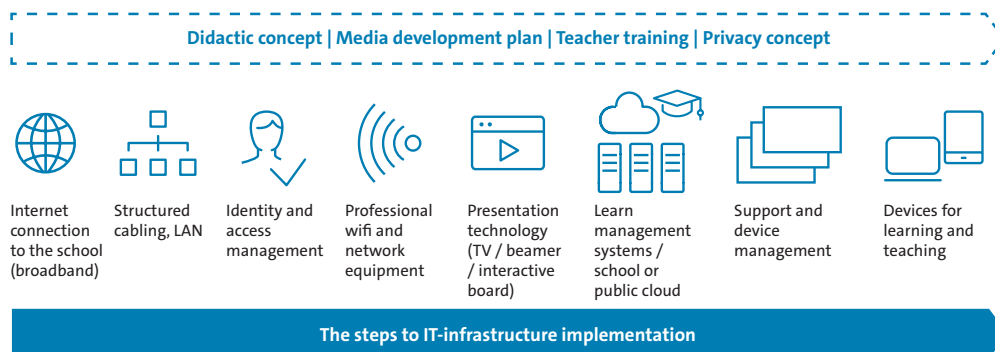
Figure 6: Participants: School authorities, school management, teachers

Network infrastructure

Network concept

Stable, trouble-free network cabling of the building is absolutely necessary for the operation of a successful IT infrastructure. The framework conditions for this are described in the cornerstone "Building infrastructure".

Different data and content call for different requirements in terms of securing and protecting the networks in which they are processed. The Ministries of Education of the Länder therefore require at least the separation of administrative and pedagogical networks (at least logically via virtual LANs, VLANs for short). Moreover, it may make sense for external devices of pupils and teachers to be connected via a separate (logical) network. An isolated network segment should also be set up for external guests who come to the school, for example, as part of an open day, as an adult education class in the late evening or as workers. Intelligent and networked devices, for example in the building services, should be isolated in another segment. However, for security reasons, the media technology for school operations itself should not be located in this network; after all, some of it is presentation equipment to which pupils and teachers may have access. Therefore, another network segment should be created for media technology. Another separate network must be used for the administrators' management access to the network components.

Hence, the ideal scenario results in a school network that is divided into at least seven logical network segments, e.g.:

- Administrative network
- Educational network
- BYOD network for external devices[8]
- Guest network
- Technical network for building services and other networked devices
- Media technology
- Management network

When accessing the network, devices must be correctly assigned to the respective network segments. This can be done dynamically and securely with various network authentication techniques. Separation via numerous different WLAN SSIDs and fixed LAN ports are outdated concepts that offer no real security, unnecessarily reduce the performance of the wireless network and require a lot of maintenance. Further and more granular distinctions do not always have to be separated into logical network segments but can also be mapped via user roles with different rights in the same network segment.

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8   Further explanations are provided in the glossary.

The following section will focus on the aspects of the active infrastructure. These must be derived from the school's goals as formulated in the school's media concept.

The infrastructure must be designed to be sustainable so that future developments can be integrated and mapped, such as:

- Integration of new device classes (introduction of mobile end devices tablets/notebooks)
- Introduction of mobile devices (high demands on WLAN)
- School-owned devices
- BYOD concept (private devices)
- Scalability (in perspective, at least 2 devices per person in the classroom, one active work device such as a tablet or laptop and one passive, but still WLAN-registered private device such as a smartphone)
- Terminal management: What effort must be made to put additional devices into operation? A device management system can provide support here.

The question of the location of the IT infrastructure is clarified in the media development plan of the school authority. The following scenarios can be implemented:

- Servers are located locally in each school. Additional costs can arise from the management of the servers.
- Servers are provided in a computer centre (communal computer centre)

Server performance is rented as a cloud service

Wired

A powerful computer network must be set up to connect the individual terminals in the class-rooms, the WLAN access points and individual buildings to each other. If possible, WLAN access points should always be connected by cable and not by meshing, as each mesh wireless bridge requires capacity in the wireless network, and this capacity is then no longer available for end devices.[9] A capacity loss of 50% per hop must be expected here. In addition, the power supply (Power-over-Ethernet, PoE) can be provided simultaneously via the Ethernet cable. The switches must support PoE for this. In addition, the switches must support logical network segmentation via VLAN so that the network concept discussed above can be implemented.[10]

Networks via power LAN (power line) are also not suitable network structures for school scena-rios.

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9   Further explanations are provided in the glossary.

10 Further explanations are provided in the glossary.

Access Switches

Criterion	Requirements	Suitable as	Remarks
Speed of the access ports	1 Gbit/s (1000BASE-T)	Minimum requirement	Sufficient for terminals
	2.5 Gbit/s or 5 Gbit/s according to IEEE 802.3bz (multi-gig)	Evaluation criterion	For current access points or workstations, bandwidths greater than 1 Gbit/s can be achieved here
Uplink-Ports	10 Gbit/s SFP+	Minimum requirement	State-of-the-art
	25 Gbit/s SFP28 or 40 Gbit/s QSFP+ or 50 Gbit/s SFP56	Evaluation criterion	Future-proof cabling to also support high-bandwidth applications and multi-gig in access
	2 Uplink-Ports	Minimum requirement	Cabling must always be redundant for fail-safe operation
	4 Uplink-Ports	Evaluation criterion	
PoE (Power-over-Ethernet)	PoE+ according to IEEE 802.3at	Minimum requirement	
	PoE Class 6 according to IEEE 802.3bt	Evaluation criterion	Powerful current AP or other devices may require more power than available via PoE+
	PoE budget according to power consumption of connected terminals	Minimum requirement	The available PoE power of the switches must correspond to what the number and type of terminals require based on the planning
Security	DHCP snooping, ARP protect, rate limiting for BUM traffic and ICMP, DHCPv6 snooping, RA guard, ND snooping, BPDU guard, port security	Minimum requirement	These functions can intercept many possible attacks or errors caused by misconfigured terminals
AAA (Authentication, Authorisation, Accounting)[11]	EAPOL according to IEEE 802.1X	Minimum requirement	
	EAP, PEAP, EAP-TLS, EAP-TTLS, EAP-TEAP	Minimum requirement	
	MAC authentication	Minimum requirement	
Management	SNMPv3, SNMPv2c	Minimum requirement	
	SSH	Minimum requirement	
	Telnet can be deactivated	Minimum requirement	
	Serial console	Minimum requirement	
	Out-Of-Band-Management	Evaluation criterion	
	TACACS for admin login	Minimum requirement	
Status display	LED lights for status, activity, speed of Ethernet ports	Minimum requirement	

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11 Weitere Erläuterungen im Glossar.

Access Switches

Criterion	Requirements	Suitable as	Remarks
Additional functions	Rapid spanning tree (LoopProtection) QoS (Quality of Service) for VoIP possibly port mirroring and logging of faulty data frames (troubleshooting) possibly link aggregation (bundling of uplink ports for higher bandwidths)	Minimum requirement	
Support	Free security patches from the manufacturer 5 years after EOS	Minimum requirement	

Core switches in two-layer networks or distribution switches in three-layer networks

Criterion	Requirements	Suitable as	Remarks
Hardware redundancy	Redundant power supply units	Evaluation criterion	Redundant power supplies not only protect the switch's hardware against failure, but also allow different power circuits to be used and thus protect against power failures.
	Hot-swappable fans during operation	Evaluation criterion	
	Redundant management modules (chassis models)	Evaluation criterion	
Downlink-Ports	10G SFP+	Minimum requirement	
	25G SFP28 or 50G SFP56 or 40G QSFP+	Evaluation criterion	Relevant in the case of access switches with corresponding uplink ports
Uplink ports (in the case of three-tier architecture models)	25 Gbit/s SFP28	Minimum requirement	State-of-the-art
	40 Gbit/s QSFP+ or 50 Gbit/s SFP56	Evaluation criterion	Future-proof cabling to also support high-bandwidth applications and multi-gig in access
	2 Uplink-Ports	Minimum requirement	Cabling must always be redundant for fail-safe operation
	4 Uplink-Ports	Evaluation criterion	
Stacking-Ports	Stacking	Evaluation criterion	Within the framework of campus networking
Port-Layout	all ports follow industry standard	Evaluation criterion	
Logical redundancies	Multi-chassis link aggregation	Minimum requirement	
Management	SNMPv3, SNMPv2c	Minimum requirement	
	SSH	Minimum requirement	

Core switches in two-layer networks or distribution switches in three-layer networks

Criterion	Requirements	Suitable as	Remarks
	Telnet can be deactivated	Minimum requirement	
	Serial console	Minimum requirement	
	API	Minimum requirement	
	Out-Of-Band-Management	Evaluation criterion	
	TTACACS for admin login	Minimum requirement	
Status display	LED lights for status, activity, speed of Ethernet ports	Minimum requirement	
Additional functions	Rapid spanning tree (LoopProtection) QoS (Quality of Service) for VoIP possibly port mirroring and logging of faulty data frames (troubleshooting) possibly link aggregation (bundling of uplink ports for higher bandwidths)	Minimum requirement	
Mounting (in the case of the core switch)	Mounting in 19-inch rack	Minimum requirement	
Routing (in the case of the core switch)	Static routing Dynamic OSPF routing	Minimum requirement	
Support	Free security patches from the manufacturer 5 years after EOS	Minimum requirement	

Don't forget: Switches   !

☐ High network speed (min. 100/1000-megabit Ethernet)
☐ Manageability (min. Layer2+)
  ▪ Possibility of network segmentation (VLAN)
☐ Power supply of end devices via PoE (e.g. 802.3at) for connection of access points
☐ Depending on the application scenario
  ▪ Use of fibre optic lines (e.g. by means of SFP modules)
  ▪ Quality of service for specific networks based on port, VLAN or TCP/UDP application
  ▪ Automatic alerts for operational support

WLAN

Access points can broadcast different WLAN networks (multi-SSID). Depending on the network, different credentials are required for use. The login information is used not only to grant access to the network, but also to divide the network into different logical network segments. For example, school-owned pedagogical end devices (e.g. school-owned laptops or tablets) can log in via a WPA3 password or with a certificate and thus gain access to services in the pedagogical network. Devices for the BYOD network, on the other hand, authenticate themselves with an individual user ID or briefly via a ticket that has been created for the teaching situation. Since the computer security of BYOD devices can only be ensured with difficulty or not at all, special

security rules must be devised here. However, special use cases should be taken into account (e.g. complete isolation leads to problems with some wireless presentation techniques).

Access point positioning

Stable WLAN reception (also in the 5 GHz frequency band) must be possible at all points in the building where mobile terminals are to be used so that a high-performance WLAN network can be made available. Reception is not measured by pure coverage, but above all by a minimum level of signal quality and thus possible bandwidth. For the most interference-free operation possible, WLAN in the more powerful 5 GHz frequency band is usually the most popular choice today, while the 2.4 GHz frequency band is only to be regarded as a supplement.

Due to the special application scenarios in schools, there are always load peaks in the use of the network (e.g. due to simultaneous watching of videos or saving of files on a file server). At the technical level, all end devices share the bandwidth of an access point. This access point should therefore be able to handle as many simultaneously active end devices as possible. One indicator for this is the antenna pattern; ideally, 4x4:4 MU-MIMO should be used for classrooms.

Due to the special usage scenarios in the school described above, an access point will have to be installed in every classroom in the future. For this reason, an RJ45 socket should already be installed in each classroom to connect an access point (see also the technical equipment of a classroom in cornerstone 4: Building infrastructure). There are various options for determining the necessary positions for the access points, each of which can take different amounts of time and effort to implement. The first possibility is to carry out a simulation using building plans. This will give you a first impression of where access points should be positioned.

In more complex environments (many small rooms, special requirements), an on-site survey is recommended. It should be noted that a site survey must always be carried out while the school is in operation, as the results obtained otherwise may deviate greatly from reality. The survey should always be based on the full extension - a survey on a partial extension can bring different results and may ultimately collide with the optimal result for the full extension.

Criterion	Requirements	Suitable as	Remarks
WLAN-Standards	IEEE 802.11ax	Minimum requirement	Current standard
	MU-MIMO in uplink and downlink and OFDMA in uplink and downlink	Evaluation criterion	For schools with higher requirements (e.g. vocational colleges), also suitable as a minimum criterion.
	Wi-Fi certification for Wi-Fi 6	Evaluation criterion	Certifies the implementation of the WLAN standard and the tested interoperability with end devices

Criterion	Requirements	Suitable as	Remarks
Ethernet-Uplinks	1×1Gbit/s	Minimum requirement	
	2.5 Gbit/s or 5 Gbit/s	Evaluation criterion	Current technology allows bandwidths > 1 Gbit/s in the WLAN, which must then also be transferred to the LAN
	Multiple uplinks	Evaluation criterion	With several interfaces, data and power connections can be redundant
Power supply	External power supply via power supply unit possible	Minimum requirement	
	PoE according to IEEE 802.3af, 802.3at	Minimum requirement	
	802.3bt	Evaluation criterion	
Model variants in the portfolio	Indoor-AP	Minimum requirement	
	Outdoor-AP	Minimum requirement	
	External antennas	Minimum requirement	
	Internal antennas	Minimum requirement	
	Dual-5-GHz	Evaluation criterion	Useful for high-density environments such as auditoriums
	5Ghz and 6Ghz	Evaluation criterion	New technology expected from second half of 2021 (market availability)
Encryption	WPA3-Personal (SAE), WPA3-Enterprise and older	Minimum requirement	
	Enhanced Open	Minimum requirement	
AAA	EAPOL according to IEEE 802.1X	Minimum requirement	
	EAP, PEAP, EAP-TLS, EAP-TTLS, EAP-TEAP	Minimum requirement	
	Redirection to captive portal	Minimum requirement	Required for guest portals
Wireless management	Automatic adjustment of channel selection	Minimum requirement	Static configurations are costly and error-prone
	Automatic adaptation of transmission power	Evaluation criterion	This feature bridges temporary failures of individual access points with the aim of ensuring uninterrupted teaching. This requires appropriate planning and surveying.
	IEEE 802.11k, IEEE 802.11r	Minimum requirement	Standards for roaming
	Intelligent BandSteering with consideration of the capabilities of the terminals	Minimum requirement	

Criterion	Requirements	Suitable as	Remarks
	Load balancing with regard to the capabilities of the terminals	Evaluation criterion	
Electromagnetic compatibility	EMC certification according to EN 60601-1-2	Minimum requirement	EMC certification (electromagnetic compatibility) according to EN 60601-1-2 means that an AccessPoint is also approved for use in medical environments.
Support	Free security patches from the manufacturer 5 years after EOS	Minimum requirement	
Network services	QoS-Tagging	Minimum requirement	Guaranteed quality for selected services such as learning software, VoIP, etc.
	Bandwidth limitation for users and applications	Evaluation criterion	Guaranteed quality of service
	Web content filtering	Evaluation criterion	
	Firewall with application detection	Evaluation criterion	Access control and QoS regulation directly at the AP engage at the first possible point and enable consideration of the requirements in the wireless performance
	Proxy for mDNS services	Evaluation criterion	Services such as AirPlay use mDNS-based service discovery, which is limited to one network segment by default; the infrastructure must work as a proxy for cross-network segment access
	Proxy for mDNS services with control according to users and user groups	Evaluation criterion	Access to mDNS-based services such as AirPlay can be enabled not only globally, but also granularly for individual users and user groups, to control exactly who has access to what

This evaluation criterion can also be taken into account in the technical criteria for routers (fulfilment must be ensured either in the WLAN area or alternatively in the router area). |

In larger schools with larger WLAN networks, it may be necessary not only to use access points but also a WLAN controller, for scaling and performance reasons. A WLAN controller can centrally control the individual access points and, depending on the model, can also perform other centralised functions. The increased performance of the controller means that even large numbers of terminals can be managed without any problems. The recommended network size for a controller can vary depending on the network manufacturer.

If a controller-based infrastructure is used, certain functions of the access points can be assumed by the controller. The exact distribution of functions between controller and access point differs depending on the network manufacturer – what matters is that the overall solution still covers the above-mentioned requirements. In addition, the central controller component should fulfil the following points:

Criterion	Requirements	Suitable as	Remarks
AP-Management	Central configuration of all connected APs	Minimum requirement	
	Central monitoring of all connected APs	Minimum requirement	
	Central troubleshooting of all connected APs	Minimum requirement	
	Discovery protocol for automatic controller detection via layer 2 and 3	Minimum requirement	Simple network structure
Architecture	WLAN traffic as independent overlay	Evaluation criterion	Decoupling from existing infrastructure
	Centralised licensing, if required	Evaluation criterion	Handling of licences should be simple and clear
Provision	Hardware controller	Minimum requirement	
	Virtual machine	Evaluation criterion	Flexible possibility to use existing server capacities
High availability	Active-active or active-passive redundancy models	Minimum requirement	
Management	SNMPv3, SNMPv2c	Minimum requirement	
	SSH	Minimum requirement	
	Telnet can be deactivated	Minimum requirement	
	Serial console	Minimum requirement	
	Out-of-band management	Evaluation criterion	
	TACACS for admin login	Minimum requirement	
LAN	STP	Minimum requirement	Prevention of loops in the network
	Static routing, OSPF	Minimum requirement	The controller is a central component and must integrate with L3
Hardware portfolio	Models with min. 2x SFP uplinks	Evaluation criterion	
Scaling	(depending on planning)	Minimum requirement	

> ## Don't forget: WLAN   **!**
>
> The technology should cover the following:
> ☐ High performance (e.g. 802.11ax)
> ☐ Dual band capability (2.4 GHz and 5 GHz)
> ☐ DFS channels in the 5 GHz band for overall higher performance
> ☐ Option for multiple WLAN networks via one device (Multi SSID)
> ☐ Encryption according to WPA3-PSK and WPA3-Enterprise (802.1X)
> ☐ Zentrale Verwaltungsmöglichkeit
> ☐ Central management option
> ☐ Depending on the application scenario:
>   ▪ Roaming (e.g. for VoiP over WLAN or other cases where an uninterrupted connection is needed when wandering around the school)

Router

Routers are the peripheral components from the Internet to the internal network. These are often provided directly by the Internet provider. The selection criterion for routers in the school environment should be security, trustworthiness and data protection.

High-speed internet and load balancing

IAs schools become more digital, the amount of data coming from and going to the Internet is increasing, and so is the bandwidth required. A powerful router is the necessary prerequisite for supporting high-speed Internet access at the respective school location. It is imperative that future-proof components are used. If the bandwidth of a single Internet connection is not sufficient, the router must support several Internet connections simultaneously, for example, to route applications with a high data volume over the best possible line (load balancing).[12] In addition, the use of several parallel internet connections ensures a high degree of fail-safety. Alternatively, the use of a mobile router for internet backup via 4G or 5G.

Criterion	Requirements	Suitable as	Remarks
Support for high-speed internet connections	ADSL, VDSL, vectoring, supervectoring, G.fast, fibre, LTE/4G, 5G, Ethernet	Minimum requirement	Flexible use of the Internet connections available at the location
Support of load balancing	Several Internet connections can be used in parallel via one device, with wireless backup in the event of failure of the wired Internet connection	Evaluation criterion	Increase in bandwidth, fail-safety
Support of VPN technology	IKEv2 IPSec VPN (recommendation: IPSec key exchange via preshared key or certificates (RSA, digital signature), AES/AES-GCM with 256 bits and SHA256 hashes)	Evaluation criterion	Secure connection to external service providers, connection to a data centre, homeschooling

12 Further explanations are provided in the glossary.

Criterion	Requirements	Suitable as	Remarks
Support of network segmentation (at least logical, if necessary, physical)	At least three (better four) sub-networks, support of multi-WAN	Minimum requirement	For separation of administrative network, pedagogical network and guest network
Gigabit Ethernet ports	At least 4 GE ports for physical network separation and additional connection to the local network	Evaluation criterion	For the physical separation of administration network, pedagogical network and guest network
Regular software updates including new security technologies	Provision of major releases with new features and release updates with general improvements and bug fixes, critical security fixes (security updates) based on the last available software version, and manufacturer support, even after discontinuation of the router	Minimum criterion	Highest investment security, long-term protection through security updates
Integrated stateful inspection firewall	Brute force password protection, alarm options e.g. via e-mail or SYSLOG, ACL for LAN/WAN, intrusion prevention, TACACS+/ RADIUS incl. IPv6	Evaluation criterion	If a dedicated firewall is not used, at least the security functions of the router should be used
Supported protocols	ARP, DHCP, DNS, ICMP RADIUS, LLDP, SNMPv3, RIP, VRRP, RIPv2, BGPv4, OSPFv2, PPPoE, GRE	Minimum requirement	Highest interoperability in heterogeneous networks and different connection types
Support of IPv4-IPv6 dual stack	6to4, 6in4, 6rd (static and via DHCP), Dual Stack Lite (IPv4-in-IPv6 tunnel)	Minimum requirement	The router can be used in either IPv4-only, IPv6-only or in mixed networks
Network services	Proxy for mDNS services with control according to users and user groups	Evaluation criterion	Access to mDNS-based services such as AirPlay can be enabled globally, as well as granularly for individual users and user groups, so that it is possible to control exactly who has access to what. This evaluation criterion can also be taken into account in the technical criteria for WLAN (fulfilment must be ensured either in the WLAN area or alternatively in the router area).

Site networking

Different locations of a school or a school authority are connected to each other with the help of VPN tunnels. These secure the private network traffic between the sites and possible private services in the cloud.

The VPN tunnels can be established via a router infrastructure with a VPN concentrator, or from router to router. The routers are configured directly or through a management system. The route selection is made locally in the respective router.[13]

Alternatively, technologies such as SD-WAN (software defined - wide area networks) can be used.[14] Here, the SD-WAN endpoints are managed centrally via a cloud infrastructure. This controls the traffic between the VPN endpoints as well as the choice of paths via the various providers, which the schools/school boards can use to achieve the required bandwidth.
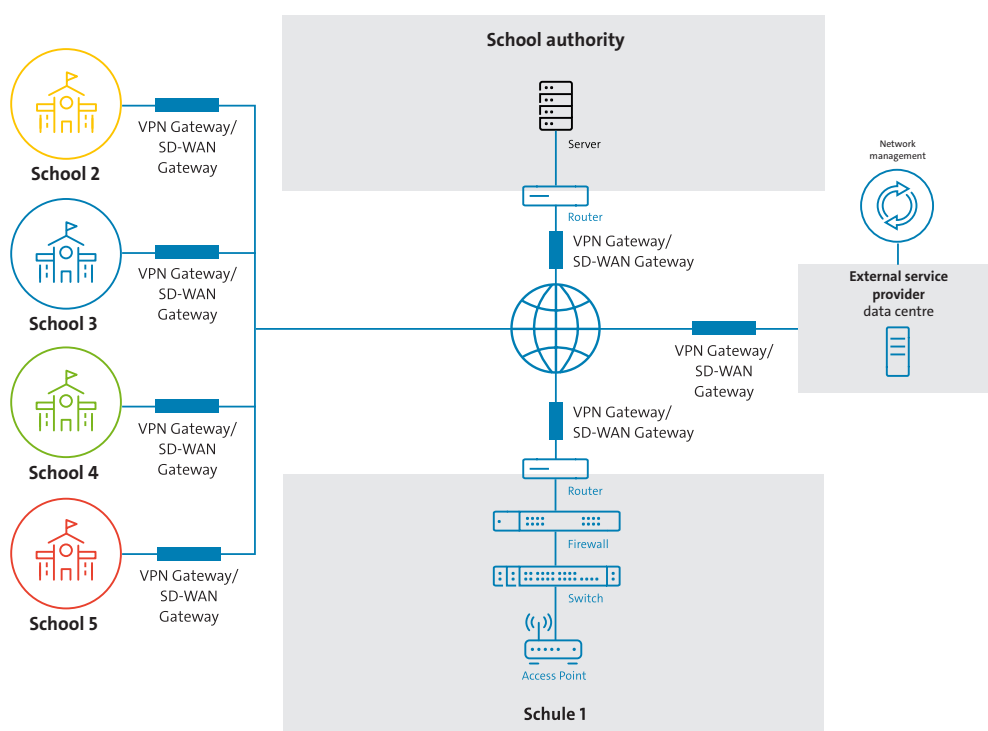
Figure 7: Site networking

4.1.3   Infrastructure security (security and data protection)

A school's network is a space that is in need of protection. Hence, security aspects should be taken into account both in the way it functions and in the choice of manufacturer.

Infrastructure security is the basis for school IT. Building on this, chapter 3.4 presents the security features of the end devices.

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13 Further explanations are provided in the glossary.

14 Further explanations are provided in the glossary.

The following security features should be available within the school network. These features can be provided through various components:

VPN

For secure connection to non-school learning locations, external service providers or to a computer centre via the Internet, the devices must support VPN encryption technology. The highly secure IPSec VPN technology (according to the current IKEv2 standard), which is widely used by many end devices and remote stations, enables the convenient and flexible connection of external network users or entire locations and service providers.

Network segmentation

As described in the section on the network concept, networks are divided into different segments to allow them to apply their own requirements and security guidelines. This type of segmentation is classically accomplished via virtual LANs (VLANs). VLANs may be mandatory for some network segments, such as the separation between pedagogy and administration.

For users, a change of network segments in a purely VLAN-based approach entails a new connection. Modern approaches to network segmentation rely on a few, necessary VLANs instead of numerous VLANs and supplement these with much more flexible user roles. For example, within the pedagogical network, pupils and teachers can be differentiated as different user roles, but also into higher and lower school or even into individual classes, if required. The role assigned to a user can easily be changed as needed, for example if a pupil needs to be given more extensive access in the context of a computer science club.

The requirements and security guidelines defined for the respective network segments can be enforced either decentrally directly at the access point to the network or centrally via a firewall. Depending on the solution, both accesses within a segment and accesses to other segments can be controlled at these points. Depending on the approach, either each VLAN or each user role can represent a network segment of its own.

Anti Spam, Anti Virus

For example, anti-spam and anti-virus applications guarantee email security in the administration network. This protects the infrastructure used in the long term as well as ensuring short-term operability. Modern solutions are based on a two-step approach: first, they check potentially dangerous files locally (e.g. on a firewall) and then, in a second step, via sandboxing in the cloud. In sandboxing, a suspicious file is preventively executed in a sealed-off environment to assess

possible attacks. Machine learning ensures that the individual security mechanisms are up to date, among other things.[15]

Anti-malware, intrusion detection/prevention

More complex cyber attacks can be detected and averted by analysing typical attack patterns with an intrusion detection and prevention system.[16] Combined with an anti-malware function, both the administrative network and the pedagogical network, or a BYOD setup, are effectively protected.

Wireless intrusion detection system

In addition to software-based attacks, a network infrastructure can also be exposed to basic hardware-based attacks. This applies in particular to WLAN networks, as wireless signals can easily spread over greater distances and, in contrast to wired networks, there is no clear demarcation between the network and the outside world. Sources of interference can therefore influence the wireless network relatively easily. Sources of interference can simply be other devices such as microwaves, which unfortunately create interference on the same wireless frequencies as WLAN when they are in operation. However, they can also be malicious attackers who deliberately paralyse a WLAN network or, in the worst case, imitate a WLAN network in order to tap into the data of the end devices.

When selecting a WLAN solution, it thus makes sense to ensure that it can detect, localise and, at best, avoid such sources of interference. The functions for detecting malicious attackers fall into the area of wireless intrusion detection and prevention. As well as detecting sources of interference, the access points can thus recognise typical patterns of attacks that can be used to disrupt wireless communication. In addition, spectrum monitoring and intelligent channel selection can help to detect and avoid non-malicious interference.

Content filter and application detection [youth protection filter functionality]

An application filter on layer 7 can be used to block individual applications such as social media and streaming services in the school network. Bandwidth management at the application level is also possible, so that applications that are essential for teaching or the administration network can be prioritised and their availability can be guaranteed. For the pupil network, especially with BYOD, a youth protection filter is necessary. Ideally this should have a teacher-controlled override function if content that is usually blocked is useful for teaching.

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15 Further explanations are provided in the glossary.

16 Further explanations are provided in the glossary.

In addition to the implementation of these essential security functions in the network, security aspects should also be taken into account when choosing a manufacturer. The following things should be implemented by the manufacturer:

GDPR

The General Data Protection Regulation comes into effect in networks when services to be provided by the network process personal data (e.g. MAC addresses, IP addresses, data security). (e.g. MAC addresses, IP addresses, login information, information about service use, e-mail addresses, etc.). This is the case, for example, with content filters or network access control and network management via cloud systems. Therefore, only solutions whose manufacturers enable GDPR-compliant use may be deployed.

If personal data are processed externally (e.g. by a system house or cloud service), the provider and the schools are obliged to conclude a contract for processing and to ensure that the implementation in the network complies with all GDPR requirements. If anything is unclear, it is recommended that a data protection impact assessment be carried out. The data protection officer is responsible for the concrete implementation here.

Common Criteria/BSI certification

The Common Criteria or BSI certification ensures that the network components meet the tested security standard, and thus contribute to the secure infrastructure in a comprehensible manner. The Common Criteria certification should be available for as many components as possible and should be up to date.

Processes for detecting and fixing security vulnerabilities

No software is error-free, which makes it even more important that every manufacturer has implemented organisational processes that check the respective solution for vulnerabilities before release and then fix them. If vulnerabilities are found by third parties after release, they can be reported to the manufacturer. The manufacturer must provide a critical incident response team (CIRT) for this purpose. The CIRT must process these and fix them according to its own specifications.

Support organisation

The manufacturer should have its own service and support organisation. This is the only way to ensure that products are replaced in the event of hardware faults or that software updates are made available. Both of these are important for the longest possible, fully functional use of network products.

The manufacturer should offer different service levels that ensure short response times when needed.

Network access control

A network needs access control to enforce the network segmentation and differentiated access rights described at the beginning of this document. In principle, no access points and switches should allow direct access to the network, but instead they should offer different service levels to ensure short response times when needed. In the course of this kind of network login, the identity of a device or user is checked and, based on this, the appropriate accesses are granted.

Several components are involved in achieving this level of secure network access: The network device, i.e. the access point or switch, initially blocks the network access and prompts the terminal devices to log in. The features needed for this are already taken into account in the above requirements. The access data already stored in the school identity management (cf. following chapters) can be used as login data for the network. A network access control (NAC) system is needed as an intermediary between network devices and school identity management.

The NAC system picks up login attempts and evaluates them. In the course of this evaluation, it is possible to check whether the specified user or device identity actually exists. For this purpose, the NAC system can query existing systems such as the school's identity management. On the other hand, in addition to the pure check, it can also retrieve further information that allows conclusions to be drawn about the access rights of this identity. This can include, for example, the position (pupil, teacher, headmaster, secretary, etc.) or the class assignment, which are also stored in the identity management system, or a device type (printer, telephone, Apple TV), which can already be recognised from the device details in the login. An MDM system (cf. the following chapters), which provides information about an end device, can be another source of information for a NAC system. The access rights for the respective device are then derived from the available information via a set of rules.

In turn, the implementation of these access rights is the responsibility of the network components such as access points or switches. In the simplest case, only a specific network segment is assigned. In more advanced concepts, roles that, alongside the allocation of a network segment, can encapsulate other settings for network access such as firewall rules, are assigned. MDM systems and dedicated firewalls can also be integrated. The NAC system then shares information with the access point or switch, as well as with these network components, so that all network subsystems are actually involved in the implementation of access rights.

Secure networks can only be implemented with this kind of network access control concept. Old concepts where switch ports are reserved for specific purposes or where a separate WLAN SSID with a pre-shared key is broadcast for each network segment provide segmentation but do not control it. Segmentation is worthless without control, as malicious or careless users can easily bypass it: All it takes at the switch is just to change to another port reserved for other purposes. In the WLAN, a large number of broadcast SSIDs lead to considerable performance losses; moreover, generally valid pre-shared keys are usually not secret for too long. In both cases, the

network operator cannot trace which users and which devices are in the network and whether they are also in the correct network segments, as no authentication takes place.

In contrast, access control that enforces a login to the network ensures that only authorised devices and users are given access. In addition, the network operator gains visibility and traceability, as devices and users are identified as part of the login process. On the administrative level, network access control also facilitates the work of network administrators: Since access rights and network segments are allocated dynamically each time based on the login, the effort required to statically configure switch ports, which may have been necessary in the past when switching devices, is eliminated. In the WLAN, multiple network segments can be provided via just one SSID, which increases the performance of the network.

Criterion	Requirements	Suitable as	Remarks
Interoperability	RADIUS according to RFC 2865, 2866	Minimum requirement	Standard for AAA
	RADIUS CoA according to RFC 3576	Minimum requirement	Addition of proactive role change to RADIUS
	Integration of manufacturer-specific RADIUS dictionaries	Minimum requirement	
Integrations	AD and other directory services via LDAP as authentication source	Minimum requirement	
	Option to integrate the firewall	Minimum requirement if commercially available firewall solution is in use	
	Option to integrate the IDM solution	Minimum requirement if a commercially available IDM solution is in use	
	Option to integrate the MDM system	Minimum requirement, provided that a commercially available MDM solution is in use	
Authentication protocols	EAP, PEAP, EAP-TLS, EAP-TTLS, EAP-TEAP	Minimum requirement	
Device recognition	Fingerprinting	Evaluation criterion	
Guest functions	Guest portals that can be freely designed	Minimum requirement	
	MAC caching	Minimum requirement	
	Workflows for registration, vouchers, sponsoring	Minimum requirement	
Interfaces	Communication interfaces (API) must be available.	Minimum requirement	

> **Don't forget: Security features** **!**
>
> (Depending on the scenario)
> ☐ Network segmentation
> ☐ Youth protection filtering (for BYOD independent of the end device and software version used/without installation requirements)
> ☐ Malware protection
> ☐ Bandwidth regulation
> ☐ Support and bundling of multiple Internet connections

> **NETWORK TECHNOLOGY CHECKLIST** **?**
>
> ☐ Who should use the school network with which devices?
>   → Definition of logical networks (how many devices, which device in which network, access restrictions, how to activate, if necessary, bandwidth restrictions)
> ☐ Which services (file storage, MDM, beamer, etc.) should be usable by which terminal (school-owned, BYOD)?
> ☐ What are the structural conditions (see checklist building infrastructure) on site?
> ☐ Are all the structural prerequisites in place?
> ☐ Where do switches for the sub-distribution have to be installed?
> ☐ Who will configure the network hardware?
> ☐ Is the network hardware compliant with European data protection (e.g. is the manufacturer obliged to install backdoors?)

4.1.4   Network management

The administration (management) of the individual network infrastructure components can be complex and can take up a lot of time. Therefore, a network management system (NMS) should be set up for each network.[17] An NMS provides the network administrators with a central interface for viewing and monitoring the status of the entire network and the individual components. LAN, WLAN and, ideally, WAN are viewed together and across the board. In addition, an NMS makes it possible to centrally initiate configuration changes and software updates for the network components.

Ideally, an NMS covers not just individual schools, but all the facilities of an institution. To give different user groups access to only individual functions and/or facilities, the NMS should include a system for role-based access.

These options are available for the provision of an NMS:

- On-premise installation in the individual facilities - but then the NMS also only covers the respective location
- Centralised installation in the institution's own data centre - the management network of the individual locations must be made directly accessible from the data centre.
- Purchase in the form of a SaaS solution - the simplest option, as only one internet access is required for each location.
- Pure monitoring access is provided by the service provider as part of a managed service - the question of the type of provision is then outsourced.

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17 Further explanations are provided in the glossary.

Criterion	Requirements	Suitable as	Remarks
Device support	WLAN and LAN hardware	Minimum requirement	
	Router and firewall	Evaluation criterion	
Monitoring	Devices with status and utilisation	Minimum requirement	
	Terminal devices with connection status	Minimum requirement	
	Bandwidths	Minimum requirement	
	Application detection	Minimum requirement	
	Aggregated overview of sites or groups	Minimum requirement	
Troubleshooting	Central overview of errors and alarms	Minimum requirement	
	Statistics on the connection quality of end devices across devices	Minimum requirement	
	Automatic problem detection with diagnosis and suggested solution	Evaluation criterion	
Management	Access to all configuration options of the devices	Minimum requirement	
	Simultaneous configuration for unit groups	Minimum requirement	
Interfaces	Documented RESTful API with access to reporting, monitoring and configuration settings	Minimum requirement	Integration with other systems

5 Procurement of presentation technology

The buzzword "digital whiteboard" is often used colloquially to describe all solutions for tea-ching/classrooms that can be used electronically with content. Current studies show that using digital whiteboards helps pupils to be better motivated and also helps them to achieve more positive learning outcomes. This is especially true in primary school. For primary students, eye-hand coordination is very important to teachers. It is uncontroversial that proven and tested didactic methods must be preserved when integrating new "digital" solutions.

Thus, the solutions must be considered in a nuanced way, especially in light of the respective use.

The digital boards have different sizes, depending on the manufacturer, and they range from 48 inches to 105 inches. The screen size of an 89-inch display is approx. 2.26 m (w200cm x h120cm). The standard size is currently 85 to 100 inches.

However, data can also be entered on the digital whiteboard directly on the computer/laptop or via a tablet or tablet PC. Put simply, the touch-enabled device then functions like an interactive whiteboard in mini format. It allows teachers to move freely around the room and interact with the board without having to stand in front of it.

It thus replaces the interactive whiteboard as an input surface. The advantage over input with a mouse on a PC is that the touch-enabled device can be moved freely.

Manufacturers specialising in the education market supply board software together with the display systems as a whiteboard and teaching software, which not only allows location-inde-pendent lesson preparation and follow-up, but also provides tools relevant to teaching. This kind of software offers a wide range of interaction options that have been specially developed for pedagogical needs. The page and animation content can be saved and retrieved and edited at any time during the lesson. For presenting and sharing information, basic applications can also be used as an alternative to whiteboard and teaching software, depending on the requirements profile.

5.1   Teaching situations

Teaching situation	Description	Important specifications:	+	−
Mobile deployment	Teachers use the technology at central locations within the school. Control by cable as well as wirelessly	- Weight - Colour brightness - Resolution - Connection options - Ease of use	- Strong demand orientation - high flexibility regarding locations of use - Simple operation	- Projection surface available? - Sound system required? - Time required for set-up and dismantling? - Management "who has the device when?"
Fixed to the ceiling	The unit is permanently bolted to the ceiling. All peripheral devices are permanently mounted. Clear availability in the classroom, always the same familiar operation. Control by cable as well as wirelessly. The system is available to the teacher alongside the familiar blackboard system.	- Colour brightness - Resolution - Aspect ratio of the image from a distance - Light source - Connection options - Ease of use	- High stability - Low costs - Simple operation - Important when renovating existing installations - Interactivity is possible for the user - Devices can be administered in the network	- Teachers can stand in the light - If necessary, Inconvenient room design (windows/cabinets etc. in the way) - No interactivity on the display surface - In older school buildings in particular, the static requirements may first need to be checked for ceiling installations.
Fixed to the wall	The device is firmly screwed to the wall. All peripheral devices are permanently mounted. Clear availability in the classroom, always the same familiar operation. Control by cable as well as wirelessly. The system is available to the teacher alongside the familiar blackboard system.	- Colour brightness - Resolution - Light source - Connection options - Ease of use	- Teachers do not stand in the light. (Projection solution) - High stability, - simple/cheaper assembly - Simple operation - Interactivity is possible for the user - Devices can be administered in the network - Surface can be used as a magnetic pin board (projection solution)	- If necessary, Unfavourable room design (windows/cupboards etc. in the way) - Permanent black surface in the room (display solution)

Teaching situation	Description	Important specifications:	+	−
Interactive digital board	The unit is firmly screwed to the wall and can be height-adjusted. It usually replaces the existing blackboard. The system is interactive and enables digital teaching even without a PC. Control by cable as well as wirelessly. All peripheral devices are permanently mounted. Clear availability in the classroom, always the same familiar operation. If the existing blackboard must stay in place, a smaller device (e.g. 65 inch) can be installed between the blackboard	• Interactivity with finger and pen on the display surface • Image size • Board texture • Brightness • Resolution • Light source • Connection options • Ease of use • Height adjustment • Service	• Teachers do not stand in the light. (Projection solution) • High stability, • simple/cheaper assembly • Simple operation • Interactivity is possible for the user • Devices can be administered in the network • Surface can be used as a magnetic pin board (projection solution) • Access to and sharing of digital content • Remote access to learning (e.g. via additional document camera and video conferencing software) • Web applications and interactive learning software • Interactive and analogue work can be done on the digital whiteboard (projection solution) • High stability, • No restrictions in the choice of didactic methods (projection solution) • Technical link between face-to-face and online classes (Solinger approach) • Devices should be administered in the network	• Permanent black surface in the room (display solution) • Extensive possibilities - users should be well trained • No analogue availability for the display solution
Large screen projection in auditorium, sports hall, theatre	Equipment for spaces with more than 50 audience members – If necessary, as permanent display (digital signage)	• Brightness • Aspect ratio of image to projection distance • Integration into existing infrastructure	• Durability of the systems • Event equipment	• Planning feeds • Plan projection surface (front/rear projection) • If necessary, Media control required

5.2 Technical criteria and requirements

Detailed explanations of the technologies listed in the following tables (including image sizes, resolution, operating time, finger and pen operation, etc.) can be found in the annex to the guide.

5.2.1 Mobile presentation

User profile	Primary level
Examples of applications	▪ Access to and sharing of digital content ▪ Video conferencing/remote access to learning ▪ Web applications & productivity tools

Criterion	Requirement	Suitable as	Comment
Weight	4kg	Maximum criterion	Einfacher Transport von Raum zu Raum
Image size	Up to 280" screen size	Minimum criterion	
	Up to 300" screen size	Evaluation criterion	
White/colour brightnesses	At least 4,000lm	Minimum criterion	Auch bei wechselnden Lichtverhältnissen sollte der Projektor über eine ausreichende Helligkeit verfügen. Weitere Informationen zur genormten Messung sind dem Glossar zu entnehmen.
Resolution	At least WXGA	Minimum criterion	
	Full HD (1080P)	Evaluation criterion	€
Zoom	At least 1.6x optically	Minimum criterion	Flexible Positionierung im Raum
Vertical key stone correction	+-30° automatic	Minimum criterion	
Horizontal key stone correction	+-30° manual	Minimum criterion	
Light source	UHE lamp min. 6,500/15,000 hrs service life of light source in normal/eco mode	Minimum criterion	
Light source	>15.000h in ECO	Evaluation criterion	
Connectivity	At least 2x HDMI in, min. 2 x VGA in, 1x VGA out, min. 1 x USB type A, audio in & out, WLAN (min. optional), 1 x LAN	Minimum criterion	For unrestricted use of stationary or mobile PCs
	Mirroring of screen contents	Evaluation criterion	For optimal use of mobile devices €

Criterion	Requirement	Suitable as	Comment
Special function	PC-free presentation	Evaluation criterion	
Power consumption	≤ 400 Watt	Minimum criterion	
Service	In the event of a fault, malfunction etc. Replacement/repair within 5 working days	Minimum criterion	
	In the event of a fault, malfunction etc. Replacement/ repair within 1 working day	Evaluation criterion	Influence on room occupancy €
Guarantee	At least 5 years	Evaluation criterion	
Sustainability certification	TCO	Evaluation criterion	Alternatively, a comparable certification Z
Training	Basic training	Minimum criterion	
	Consolidation 1: Training for disseminators at school 2H (courses with max. 6 participants)	Evaluation criterion	€

5.2.2　Ceiling mounting (display only)

User profile	Primary level
Examples of applications	▪ Renovation of already existing facilities, etc. ▪ Video conferencing/remote access to learning ▪ Web applications & productivity tools

Criterion	Requirement	Suitable as	Comment
Image size	Up to 300" screen size	Minimum criterion	
	Up to 500" screen size	Bewertungskriterium	€
Projector/image			
White/colour brightnesses	4000 lm	Minimum criterion	The projector should be sufficiently bright even under changing lighting conditions. For more information on standardised measurement, see the glossary.
	≥ 5000 lm	Evaluation criterion	For even better legibility. For more information on standardised measurement, see the glossary. €
Resolution	Full HD (1080 P)	Minimum criterion	
	>Full HD e.g.: WUXGA	Evaluation criterion	€

Criterion	Requirement	Suitable as	Comment
Zoom	At least 1.6x optically	Minimum criterion	Flexible installation, also ideal for replacement
Vertical key stone correction	+-30° manual or automatic	Minimum criterion	Simple image correction
Horizontal key stone correction	+-30° manual or automatic	Minimum criterion	
Light source	UHE lamp min. 5,000/10,000 hrs service life of the light source in normal/eco mode	Minimum criterion	
	Laser light source min. 20,000h/30,000 hrs service life of light source in normal/eco mode	Evaluation criterion	Investment security **€**
Connectivity	At least 2x HDMI in, min. 2 x VGA in, 1x VGA out, min. 1 x USB type A, audio in & out, WLAN (min. optional), 1 x LAN	Minimum criterion	For unrestricted use of stationary or mobile PCs
	Mirroring of screen contents	Evaluation criterion	For optimal use of mobile devices **€**
Power consumption	≤460 Watt	Minimum criterion	
	<360 Watt	Evaluation criterion	**€**
Service	In the event of a fault, malfunction etc. Replacement/repair within 5 working days	Minimum criterion	
	In the event of a fault, malfunction etc. Replacement/ repair within 1 working day	Evaluation criterion	Influence on room occupancy **€**
Guarantee	At least 5 years	Evaluation criterion	
Zertifizierung für Nachhaltigkeit	TCO	Evaluation criterion	Alternatively, a comparable certification **Z**
Training	Basic training	Minimum criterion	
	Consolidation 1 Training for disseminators at school 2H (courses with max. 6 participants)	Evaluation criterion	**€**

5.2.3   5Wall mounting only as a display system

User profile	Primary level
Examples of applications	• Access to and sharing of digital content • Video conferencing/remote access to learning • Web applications & productivity tools

Criterion	Requirement	Suitable as	Comment
Size	≥ 85"	Minimum criterion	
Elevation/type of mounting	Fixed wall mounting	Minimum criterion	
White/colour brightnesses	At least 3,500lm	Minimum criterion	Even in changing light conditions, the projector should be sufficiently bright. For more information on standardised measurement, see the glossary.
Ratio	< 0,3:1	Minimum criterion	
Resolution	WXGA	Minimum criterion	
	Full HD (1080P)	Evaluation criterion	
Light source	UHE lamp min. 5,000h/10,000 hrs service life of the light source in normal/eco mode	Minimum criterion	€
	Laser light source min. 20,000h/30,000 hrs service life of light source in normal/eco mode	Minimum criterion	Investment security
Connectivity	min. 3 x HDMI input, min. 1 x VGA in and 1 x out, WLAN (min. optional), min. 1 x USB type A, audio in & out	Minimum criterion	
Power consumption	≥ 460 Watt	Minimum criterion	
	< 270 Watt	Evaluation criterion	€
Sound	External active loudspeakers min. 2 x 10W stereo	Minimum criterion	Recording at the whiteboard system necessary for sound transmission in a classroom
Service	In the event of a fault, malfunction etc. Replacement/repair within 5 working days	Minimum criterion	
	In the event of a fault, malfunction etc. Replacement/ repair within 1 working day	Evaluation criterion	Influence on room occupancy
Guarantee	At least 5 years	Evaluation criterion	€

Criterion	Requirement	Suitable as	Comment
Sustainability certification	TCO	Evaluation criterion	Alternatively, a comparable certification
Training	Basic training	Minimum criterion	
	Consolidation 1 Training for disseminators at school 2H (courses with max. 6 participants)	Evaluation criterion	

5.2.4   Interactive whiteboard system

Interactive board system as height-adjustable folding sliding board (projection)

User profile	Primary level
Examples of applications	▪ Access to and sharing of digital content ▪ Remote access to learning (e.g. via additional document camera and video conferencing software) ▪ Web applications and interactive learning software ▪ Basic functions: interactive or analogue work on the board

Criterion	Requirement	Suitable as	Comment
Size	≥85" White board for the central area Double-sided board wings individually selectable - whiteboard/greenboard - with squares/lines ...	Minimum criterion	Interactive whiteboard system for digital (with finger and interactive pens) and also analogue teaching (with water-soluble pens/chalk)
Elevation/type of mounting	Permanently installed height-adjustable pylon system for projector and folding sliding board	Minimum criterion	Incl. Projector mount
Surfaces	Magnetic steel enamel board	Minimum criterion	Rewritable board with water-soluble pens & projection surface can also be used as a magnetic "pinboard"
Projector/image			
White/colour brightness	At least 3,500lm	Minimum criterion	Even in changing light conditions, the projector should be sufficiently bright.
Ratio	<0,3:1	Minimum criterion	
Resolution	WXGA	Minimum criterion	
	Full HD (1080P)	Evaluation criterion	

Criterion	Requirement	Suitable as	Comment
Light source	UHE lamp min. 5,000h/10,000 hrs service life of the light source in normal/eco mode	Minimum criterion	
	Laser light source min. 20,000h/30,000 hrs service life of light source in normal/eco mode	Evaluation criterion	€
Interactivity	Yes - can be used with finger and pen	Minimum criterion	
	The possibility of different assignments (e.g. colour) of the pens and the finger must be possible	Evaluation criterion	
Image size	>= 85" can be used interactively	Minimum criterion	
Connectivity	min. 3 x HDMI input, min. 1 x VGA in and 1 x out, WLAN (min. optional), min. 1 x USB type A, audio in & out	Minimum criterion	For unrestricted use of stationary PCs and mobile devices. Additional devices such as Apple TV or other screen mirroring options may be necessary
Power consumption	≤ 370 Watt	Minimum criterion	
	< 270 Watt	Evaluation criterion	€
Accessories	At least 2 pens supplied	Minimum criterion	Essential tool for pedagogical and didactical communication
	3 pens or more	Evaluation criterion	€
Sound	External active loudspeakers min. 2 x 15W stereo	Minimum criterion	Recording at the whiteboard system necessary for sound transmission in a classroom
Service	In the event of a fault, malfunction etc. Replacement/repair within 5 working days	Minimum criterion	
	In the event of a fault, malfunction etc. Replacement/ repair within 1 working day	Evaluation criterion	Influence on room occupancy €
Guarantee	At least 5 years	Evaluation criterion	
Sustainability certification	TCO	Evaluation criterion	Alternatively, a comparable certification Z

Criterion	Requirement	Suitable as	Comment
Training	Basic training	Minimum criterion	
	Consolidation 1 Training for disseminators at school 2H (courses with max. 6 participants)	Evaluation criterion	€
	Consolidation 2 Training for disseminators with teaching components 4H (Courses with max. 6 participants)	Evaluation criterion	€

Interactive board system as height-adjustable folding sliding board (display)

User profile	Primary level
Examples of applications	▪ Access to and sharing of digital content ▪ Remote access to learning (e.g. via additional document camera and video conferencing software) ▪ Web applications and interactive learning software ▪ Basic functions: interactive or analogue work on the board

Criterion	Requirement	Suitable as	Comment
Size	> 84" Whiteboard for the central area Double-sided board wings (100x120cm) individually selectable - whiteboard/greenboard - with squares/lines ...	Minimum criterion	Interactive whiteboard system for digital (with finger and interactive pens) and also analogue teaching (with water-soluble pens/chalk)
Brightness	At least 400 cd/m²	Minimum criterion	
Resolution	> 1920 × 1080 Full HD	Minimum criterion	
Connections	USB touch connection/OPS-PC plug-in calculator	Minimum criterion	For integration of external computers via the touch function
Connections	3 HDMI inputs	Minimum criterion	For connecting external teacher-student devices and e.g. DVD or BD player via HDMI
Power consumption	≤ 370 Watt	Minimum criterion	
	< 270 Watt	Evaluation criterion	€
Accessories	At least 2 pens supplied	Evaluation criterion	Essential tool for pedagogical and didactical communication
	3 pens or more	Evaluation criterion	€

Criterion	Requirement	Suitable as	Comment
Interactivity	Yes - can be used with finger or pen	Minimum criterion	
Service	In the event of a fault, malfunction etc. Replacement/repair within 5 working days	Minimum criterion	
	In the event of a fault, malfunction etc. Replacement/ repair within 1 working day	Evaluation criterion	Influence on room occupancy €
Guarantee	At least 5 years	Minimum criterion	
Sustainability certification	TCO	Evaluation criterion	Alternatively, a comparable certification Z
Training	Basic training	Minimum criterion	
	Consolidation 1 Training for disseminators at school 2H (courses with max. 6 participants)	Evaluation criterion	€
	Consolidation 2 Training for disseminators with teaching components 4H (Courses with max. 6 participants)	Evaluation criterion	€

5.2.5 Equipment for auditoriums, refectory, theatre and gymnasium

Lenses must be tendered separately as required.

Criterion	Requirement	Suitable as	Comment
Image size	Up to 500" screen size	Minimum criterion	
White/colour brightnesses	At least 6,000lm	Minimum criterion	The projector should be sufficiently bright even under changing lighting conditions or with large projection surfaces.
Resolution	WUXGA	Minimum criterion	
Mounting type	Ceiling installation		
Zoom	At least 1.2x optically	Minimum criterion	Flexible positioning in the room
	At least 1.6x optically	Evaluation criterion	
Lens shift	Manual or motorised, +-50% vertical +-18% horizontal	Minimum criterion	Adjustment directly on the projector to the prevailing projection surface
Light source	Laser light source, min. 20,000h normal mode/ 30,000h ECO mode	Minimum criterion	

Criterion	Requirement	Suitable as	Comment
Connectivity	At least 1x HDMI in, min. 1 x VGA in, min. 1x Audio in, WLAN optional	Minimum criterion	For unrestricted use of stationary or mobile PCs
	1x Audio Out, 1x VGA out, 1x LAN, 1x HDBaseT	Evaluation criterion	
Sound	External speakers/speaker system		Depending on room size
	Mirroring of screen contents	Evaluation criterion	Possible via additional hardware €
Service	In the event of a fault, malfunction etc. Replacement/repair within 5 working days	Minimum criterion	
	In the event of a fault, malfunction etc. Replacement/ repair within 1 working day	Evaluation criterion	Influence on room occupancy
Guarantee	At least 5 years	Minimum criterion	
Sustainability certification	TCO	Evaluation criterion	Alternatively, a comparable certification. A laser light source is more sustainable than lamp projectors Z
Training	Basic training	Minimum criterion	
	Consolidation 1 Training for disseminators at school 2H (courses with max. 6 participants)	Evaluation criterion	

PRESENTATION TECHNOLOGY CHECKLIST   **?**

☐ Which teaching scenarios and needs should be fulfilled?
☐ What is the max. available room depth/what is the required image size?
☐ How will external devices be connected to the presentation technology (e.g. USB, HDMI, wireless)?
☐ Should the presentation technology be set up as a blackboard system?
☐ Are different didactic methods (chalk, magnet, pen, digital, mobile devices, cameras, etc.) desired/required?
☐ Is the presentation technology compatible with existing components (school server, network router, etc.)?
☐ Is there teaching and blackboard software in German?
☐ Can the software be used by all pupils and teachers in a school?
☐ Are updates available online (and free of charge)?
☐ How are the digital whiteboards supported via the manufacturer? Is regional support near the school ensured? What are the response times? What does the service concept look like?
☐ What training concept does the manufacturer have for the use of the teaching software and applications? What support is available?

6 Award criteria

It is permissible under public procurement law to require bidders to make appropriate measurements for relevant requirements and to prepare the corresponding measurement reports.

Obtaining measurement reports allows potential deficiencies in the performance of the equipment offered to be taken into account during the bid evaluation phase - i.e. before a contract is awarded.

Alternatively, once requested by the contracting authority, the preparation of a measurement report can therefore only be requested of the most economical bidder according to the file (the request can also be issued to several economical bidders). A general waiver of the requirement to obtain measurement reports may be considered, e.g. in the case of very small quantities.

The contract must be awarded to the most economical tender in accordance with section 127 of the Act against Restraints of Competition. The most economical tender is determined on the basis of the best price-performance ratio. In addition to price or costs, qualitative, environmental or social award criteria may also be taken into account. In the case of supply services relevant to energy consumption, energy efficiency must be given due consideration as an award criterion, Section 67 (5) VgV.

The performance requirements can be formulated in the context of award criteria with minimum technical requirements or in the context of evaluation criteria. It is up to the procuring entity to decide which category to assign individual performance characteristics to. Criteria usually specify minimum requirements that are essential for the intended use of a device. Where this guide recommends minimum requirements for the equipment, this is marked with "minimum requirement" in the criteria tables. If the criteria or requirements are marked with "evaluation criterion", the guide recommends using these requirements only in the context of evaluation criteria.

The formulation of the performance requirements with the aid of evaluation criteria can grant the competitors specific leeway to allow for a differentiated consideration of the services offered in the evaluation. In this way, the individual characteristics of the competitors' services can be taken into account, which promotes more diversified competition. Care should be taken when formulating the performance requirements to present a detailed, comprehensible and objectively assessable horizon of expectations or evaluation.

The increased or even exclusive application of minimum technical requirements in the tender specifications entails the risk of an undesirable restriction of competition.

The guide recommends the use of evaluation criteria to promote the widest possible competition.

7 Contractual provisions

7.1   EVB-IT

The provision of the tendered services or the delivery of the tendered products after successful completion of the award procedure is based on appropriate contracts. To support the contracting authorities, the Federal Ministry of the Interior and Bitkom have drawn up various contracts which can be used for this purpose. The contracts can be found on the website of the Federal Government Commissioner for Information Technology (↗ **https://www.cio.bund.de/Web/DE/ IT-Beschaffung/EVB-IT-und-BVB/Aktuelle_EVB-IT**).

8 List of tables

Annex A: Glossary/Explanations of technology

Procurement of terminal equipment:

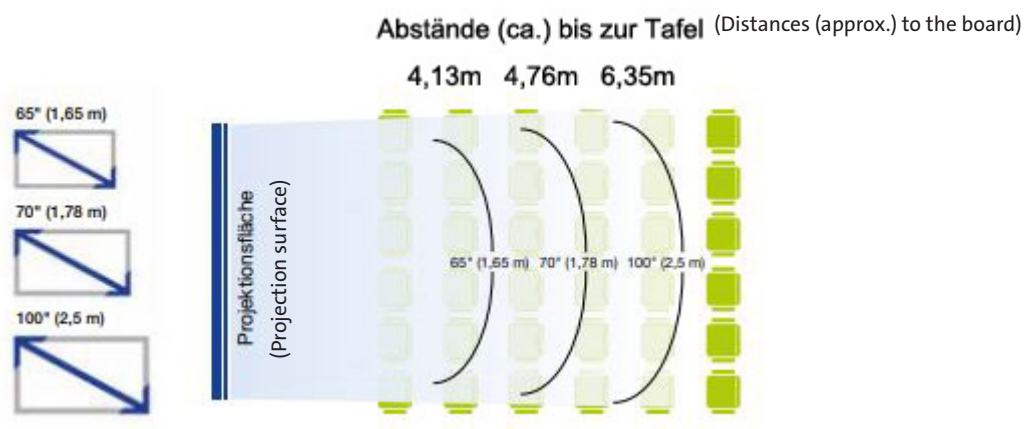|	
Clamshell	Standard notebook/laptop - no tablet functionality (max. touch input - no pen input/display max 180 degrees foldable)
Convertible	Notebook with tablet function due to 360-degree foldable display - touch input and mostly pen capable - keyboard not detachable
Detachable	Tablet with (optional) dockable keyboard via integrated connectors (not Bluetooth) - input can be done with touch and pen

Procurement of infrastructure:

AAA (Authentication, Authorisation, Accounting)	AAA stands for a security concept under which Authentication, Authorisation and Accounting are combined. Authentication means verifying identity. Authorisation determines whether a certain user is allowed to use a certain service. Accounting refers to recording and documenting the use of a service by a user.
BYOD concept	A concept for integrating private mobile devices such as laptops, tablets or smartphones into the networks of companies or schools, universities, libraries and other (educational) institutions ("bring your own device").
Intrusion detection and prevention system	An intrusion detection or intrusion prevention system (IDS/IPS) is a security solution that monitors a network or a network component such as a server or a switch and seeks to detect rule violations and harmful incidents such as hacker attacks, and then to ward them off to some extent automatically.
Load balancing	Load balancing refers to the distribution of communication streams over more than one physical connection. Load balancing is always a property between two directly connected devices. Depending on the load balancing algorithm used and the capability of the network devices, Ethernet addresses, IP addresses or other characteristic elements of the data stream are used.
Logical network structure	In contrast to the physical network structure, the logical network structure defines virtual networks (VLANs), IP address spaces, routing instances, i.e. the configuration of the network
Meshing	If access points cannot be connected via a direct LAN connection, e.g. in outdoor areas, then meshing allows this connection to be established via the WLAN. Since more than one AP can be connected in this way, it is referred to as a network of connections (mesh)
Network Management System (NMS)	NMS is a general term for the software and/or hardware that performs network management. This includes all functions and components needed to monitor and control networks
Sandboxing	Sandboxing is a term from the computer security field that refers to separating a programme from other programmes into a discrete environment so that in the event of errors or security problems, these problems do not spread to other areas of the computer.
SD-WAN (Software defined – wide area networks)	SD-WAN (software defined wide area network) is a method of installing data networks. Network management is handled by software applications.

WAN	WAN is the abbreviation for "Wide Area Network". In contrast to a LAN ("Local Area Network"), a WAN is not limited to connecting local computers and systems but covers a large geographical sector.
VLAN / VXLAN	A Virtual Local Area Network (VLAN) is a logical subnet within a switch or an entire physical network. It can extend across multiple switches. A VLAN separates physical networks into subnets by ensuring that VLAN-capable switches frames (data packets) are not forwarded to another VLAN (although the subnets may be connected to common switches) A VLAN is a layer-2 (cf. OSI layer model) domain that can extend over a network infrastructure. All devices connected in this VLAN are in the same layer-2 network.
VPN concentrator	The VPN concentrator is a collection point for several VPN connections.

Procurement of presentation technology:

Image sizes	The max. size of a usable image in the classroom, regardless of the technology, depends on simple physical circumstances
	Screen lower edge – If people are seated in front of and behind each other, the image content is not fully visible below 1.2 m above the floor - this varies according to the seating and height of the audience. A fixed installation with the lower edge of the screen less than 100 cm above the floor is considered inadequate.
	Screen upper edge – Here, especially with interactive solutions, it is important to ensure that teachers can easily reach the buttons in the upper part of the screen without aids. 215 cm is the usual measurement here. This can only be reliably achieved with height-adjustable mounting.
	Screen height – room height minus 120 cm plinth area (poorly visible plinth area) gives the mathematically maximum screen height in the respective room.
	Screen width – the screen height divided by the format to be displayed - e.g..: Full HD 16:9 - gives the screen width. (Room height 300cm - base area of 120 cm = 180cm screen height. This is to be divided by 9 when used with Full HD content X 16 and results in a screen width of 320cm.

Abstände (ca.) bis zur Tafel (Distances (approx.) to the board)

4,13m 4,76m 6,35m

65" (1,65 m)

70" (1,78 m)

100" (2,5 m)

Projektionsfläche (Projection surface)

65" (1,65 m) 70" (1,78 m) 100" (2,5 m)

Laser/lamp in projectors	The only difference between a lamp and laser projector is the light source. What happens after the light is emitted is identical for both types of projector. The lamp (UHE, gas discharge lamp) directs the light beam directly to the colour wheel or the LCD chips (see point DLP/LCD). The laser, or more precisely a mostly blue laser bank equipped with small LEDs, directs blue light partly to a phosphor wheel and partly to a diffuser that "scatters" the hard laser light. The phosphor wheel excites the blue light so that it turns yellow and is then merged with the blue light. Yellow is composed of green and red light, and together with blue the three primary colours are combined again. The superimposition of the three primary colours produces white light again, and this is transmitted to the colour wheel or the LCD chips.
Operating time	With respect to operating time, the type of light source used for projection must be taken into account. There are two predominant types of light sources here: The lamp source and the laser source. However, the technology of the projector itself is independent of the light source type, i.e. the setup of a lamp or laser projector is identical once the light is emitted. Even if the lamp life has improved over time (about 6,500h in normal mode), it does not come close to the life of the laser light source, which most manufacturers quote as 20,000h. ECO mode, where the brightness (lumens) is reduced to extend the runtime, can sometimes deliver up to 17,000h (laser 30,000h) for a lamp unit. The average life of an LCD display is usually given as 40,000h at 25° Celsius. However, the display must be adjusted correctly; if this is not the case and the operating temperature is higher than 25 degrees, the service life decreases. It also decreases if the operating current is above an operating value (normally 350mA). The higher current provides significantly more brightness, but at the expense of operating time. There are also manufacturers that quote higher figures for service life (approx. 60,000).
Image brightness: Measurement and significance	Image brightness/white brightness is the most important indicator for a projector and is expressed in lumens (lm). As the lumen number increases, the price of the projector usually increases as well, since this number is an indicator of a projector's performance. However, the type of measurement should be taken into account, since standardised measurement is the only way to make a fair comparison between all manufacturers. For this reason, only projectors that have been measured by the ISO (International Organization for Standardization) can be compared with each other. The current ISO standard is ISO21118:2012. It uses a sensor to measure the amount of light hitting the projection surface. The projection surface is divided into nine quadrants (3 width x 3 height) and a central measurement is taken in each of these quadrants. The sum of the measurements is then divided by nine (sum of the quadrants) and the result determines the lumen rating of the projector. Some manufacturers also state the colour brightness in the data sheets of their projectors. This is a value that indicates the brilliance of the colours reproduced. The colour brightness should normally be as high as the white brightness to provide a high-quality image. Unfortunately, only a few manufacturers specify this very important parameter. The luminosity/brightness of displays is given in candela/m². The higher the ambient brightness, the more powerful the display should be. Common specifications are: Up to 500 cd/m²: Rooms with darkening options 500 to 700 cd/m²: Normal (classrooms) to high ambient light (assembly hall, reception hall), no sunlight From 700 cd/m²: Bright ambient light with sunlight
Resolution: Pixels	There are various resolutions, i.e. the number of available pixels. The more pixels, the finer and steadier the image appears to the viewer. These common resolutions have largely established themselves on the market: WXGA: 1280 x 800 pixels (width x height) Full HD: 1920 x 1080 pixels WUXGA: 1920 x 1200 pixels 4K: 3840 x 2160 pixels (more common in displays)

Projection technologies: DLP/LCD	The two predominant projection technologies are LCD (Liquid Crystal Display) and DLP (Digital Light Processing) and differ fundamentally in the way they work. In this section we compare 3LCD technology (3 separate chips are used for imaging) with 1-chip DLP, where only one chip is used. Although there are also 3-chip DLP projectors in which 3 chips are also used, since we are working in the field of education and the costs for a 3-chip DLP are significantly higher than those of a 3LCD or 1-chip DLP projector, it would not make sense to equip the entire country with these projectors. DLP: A colour wheel, on which the three primary colours red, green and blue are usually applied in equal parts, is used here. Light is shot through this colour wheel and depending on which colour is in the light cone, it is passed on to the chip, known as a DMD (Digital Mirroring Device) chip. There are millions of tiny mirrors on this chip that can be tilted and are responsible for the brightness of the image. If the mirror is completely open, all the brightness is passed on to the projector lens; if the mirror is closed, no brightness information is passed on. The intermediate area between open and closed is used for the grey levels. Since each colour/brightness level is passed on to the lens individually and in sequence, this is called sequential image display. The extremely fast rotation of the colour wheel presents a completely coloured image to our brain. LCD: In this technology, the light is directed via special mirrors onto three chips, each of which is assigned to one basic colour. These chips consist of liquid crystals that align themselves according to the intensity required in a pixel. To this end, they are attached with high precision to a prism, which combines the three colours and mixes them in such a way that a coloured image is created and can then be passed on to the lens. Here, the image, or one image at a time, is displayed. Advantages of DLP: Higher contrast due to mirror system, less maintenance required, slightly cheaper. Disadvantages of DLP: "Rainbow effect" (viewer sees flickering in the image, caused by sequential display, appears disturbing) can occur, many moving parts (colour wheel, mirror), colour display significantly reduced, as only one colour is relayed at a time. Advantages of LCD: Brilliant colour representation, no rainbow effect Disadvantages of LCD: somewhat more expensive, contrast impression somewhat lower, as light still passes through the chip even in black.
Display technologies	In professional displays, the predominant technology is LCD (Liquid Crystal Display) technology. In a similar way to LCD projectors, liquid crystals are used here These are distributed over the entire projection surface and are usually illuminated by an LED light source (rarely or formerly fluorescent tubes). There are two types of illumination: Edge LED (LEDs mounted in the edges, distributed over the entire surface by means of small mirrors) and LED backlight (illumination over the entire surface). Advantages/disadvantages of edge LED: inexpensive/not completely uniform illumination. Advantages/disadvantages of LED backlight: more expensive because it uses many more liquid crystals/higher contrast is possible. A more recent development is OLED technology, which uses organic, self-luminous light-emitting diodes, thus eliminating the need for backlighting. Besides the higher price, the lifespan of the light-emitting diodes is still a problem, but faster response times and higher contrasts are possible, with the added benefit of lower heat generation.

Finger or pen control	The integration of annotations or the control of the source (e.g. PC or laptop) via the projection surface is possible by means of a stylus, which is usually included in the scope of delivery, or the finger.

With projectors, there are usually two different technologies that interact with each other after calibration. The pen functions more or less like the remote control of a television at home: after the tip of the pen hits the screen, an infrared signal is sent to the built-in camera and the currently set command is executed.

For the finger, a touch unit is usually mounted above the projection surface, and it projects an invisible laser curtain directly above this surface. When the finger pierces this curtain, the previously selected command is localised, executed and directly displayed via the camera.

The displays usually use the infrared technology already described above for projectors or, alternatively, projected capacitive technology, which enables both pen and finger input. Built-in, intersecting conductor paths create fields that recognise the X and Y coordinates via voltage changes between them when a finger or (capacitive) stylus approaches. This allows the position to be recognised and the set command to be executed at that location. Since no electronics are built into the surface, protective layers can be applied to protect the display from vandalism, liquids or scratches.

Multi-touch operation is possible for both the projection and the display, i.e. several simultaneous commands can be executed. |
| **Wireless image/sound transmission (Miracast, Apple TV, Chromecast, Intel Unite etc.)** | Miracast was defined in 2012 by the Wi-Fi Alliance as a wireless standard for peer-to-peer connections (equal participants in a network) for the wireless transmission of a screen to a projection source. It is a protocol that is implemented in the operating system of the device to make it Miracast-enabled. After the Miracast function is activated, a source (smartphone, tablet, PC) searches the wireless environment for suitable devices to connect to. When one is found and selected, the connection is established within a few seconds. Now the source image can be seen on the end device, usually via a screen mirroring interface of this end device.

AirPlay is an interface for wireless transmission of content from iOS, iPadOS and macOS devices to AirPlay-enabled receiving devices such as speakers, AV receivers, stereo systems and televisions. Technically, AirPlay is a streaming protocol developed by Apple that can be licensed by other manufacturers for installation in receiving devices. The playback device is connected via HDMI. The source uses WLAN for transmission.

The AirPlay protocol supports peer-to-peer AirPlay mode, which allows an Apple TV from the 3rd generation onwards to connect to an iOS device, for example, without having to configure it to an existing WLAN beforehand. The automatic configuration takes place via Bluetooth, and the actual data transfer takes place via WLAN as before. An increasing number of manufacturers are now also integrating AirPlay 2 as a video streaming client with the AppleTV app into their smart devices, such as SmartTVs. This allows the video signal to be transmitted directly without an AppleTV.

AppleTVs can be fully configured using an MDM system. The configuration is fully automatic, including access restrictions and conference room mode to hide commercial content. Other areas of application such as digital signage, notice boards, substitute timetables, etc. can be mapped using AppleTV apps.

However, there are also numerous possibilities on the market, e.g. via low-priced HDMI dongles, to equip an end device that is not actually Miracast/Airplay-capable with this technology. More costly, professional all-in-one solutions for mirroring screen content are also available on the market. |
| **W-LAN** | The wireless interface can be used with projectors/displays to establish a screen-mirroring connection or to integrate them into an existing network. This allows the unit to communicate with other participants in this network or to be managed remotely, e.g. via management software.

This interface is either already built into the projector or is enabled by means of a Wi-Fi dongle. In the case of the display, the Wi-Fi connection is usually already integrated. |

| Device administration | For a projector/display to be operated safely, it must be adequately administered. The administrator should integrate the device into a network (with cable or wirelessly) so that it can be controlled via management software, as already mentioned.

Particularly in a school environment, passwords must be centrally assigned by an administrator to protect functions that should not be freely accessible. For example, the switching on of the device, as well as the network settings or the screen mirroring settings, can be protected by a password. The control panel can also be locked directly on the unit and the remote-control receivers can also be locked on many projectors/displays, something that can also be useful depending on the environment. |

Annex B: Delimitation of operating systems

In addition to the operating systems for mobile devices (Android, Chrome and Windows) mentioned in the guide, there are other solutions available on the market. For example, these are:

- Apple iOS / iPad OS
  Devices with the Apple iOS or iPad OS operating systems are not explicitly the subject of this guide. Recommendations in the guide could also apply to iOS or iPad OS devices; differences may arise, for example, in processor architecture, main memory and, of course, the recommendations for the operating system.
- Linux
- Unix

Bitkom represents more than 2,700 companies of the digital economy, including 1,900 direct members. Through IT- and communication services alone, our members generate a domestic annual turnover of 190 billion Euros, including 50 billion Euros in exports. The members of Bitkom employ more than 2 million people in Germany. Among these members are 1,000 small and medium-sized businesses, over 500 startups and almost all global players. They offer a wide range of software technologies, IT-services, and telecommunications or internet services, produce hardware and consumer electronics, operate in the digital media sector or are in other ways affili ated with the digital economy. 80 percent of the members' headquarters are located in Germany with an additional 8 percent both in the EU and the USA, as well as 4 percent in other regions of the world. Bitkom promotes the digital transformation of the German economy, as well as of German society at large, enabling citizens to benefit from digitalisation. A strong European digital policy and a fully integrated digital single market are at the heart of Bitkom's concerns, as well as establishing Germany as a key driver of digital change in Europe and globally.

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