ENABLING RELIABLE DIGITAL HOSPITALS

Building a Stronger, More Resilient IT Infrastructure

Contents

Executive Summary

Digital Imaging and Communications in Medicine (DICOM) is the standard for handling, storing, printing, and transmitting information in medical imaging. This method allows physicians to store, exchange and transmit medical images from devices such as scanners to printers and computers, allowing for the integration of medical imaging equipment with other devices. All relevant systems are increasingly becoming connected to Picture Archiving and Communications Systems (PACS), Radiology Information Systems (RIS), Hospital Information Systems (HIS), as well as to the hospital intranet and wider Internet. A physical infrastructure which is unable to support these applications can result in unexpected downtime and non-compliance. The following white paper will help to properly size the physical infrastructure when medical imaging and diagnostic equipment will be used, with a focus on power and cooling systems.

Introduction

Over the years, the expansion of IT and numerous technologies in medical imaging scanners has made room for their evolution into powerful new devices used for diagnostics and interventional radiology. The information generated by these products help with early detection and treatment of diseases, such as cardiology, neurology, oncology, orthopedics and surgery, resulting in significant improvements in patient care. A typical medical imaging and diagnostic equipment network is illustrated in the picture below.

This network can be broken down into subcategories:

- **Modalities** that capture and generate the images
- **Picture Archiving and Communications Systems (PACS)** that store generated images and make them available to physicians for diagnosis and treatments. It provides faster access to diagnostic information, reducing the need for film and film storage, in turn eliminating the problem of lost films and increases radiologist and physician satisfaction and productivity
- **Radiology Information Systems (RIS)** and **Hospital Information Systems (HIS)** that not only monitor and manage the workflow of radiology departments, but entire hospitals—from patient check-in to scheduling, billing and generating electronic medical records and management reporting
- **Computed Radiography**, which converts films to digital images
- **Digital Radiography**, which provides digital images
- **Laser printers and other peripherals**, which prints films when required

Modalities involve several scanning techniques to visualize the human body for diagnostic and treatment purposes, which include: Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Angiography Therapies (AT), Positron Emission Tomography (PET) and Ultrasound (US). They are connected to PACS and RIS/HIS through Local Area Networks, Wireless Networks, or Wide Area Networks. PACS often have a dedicated Storage System to store all

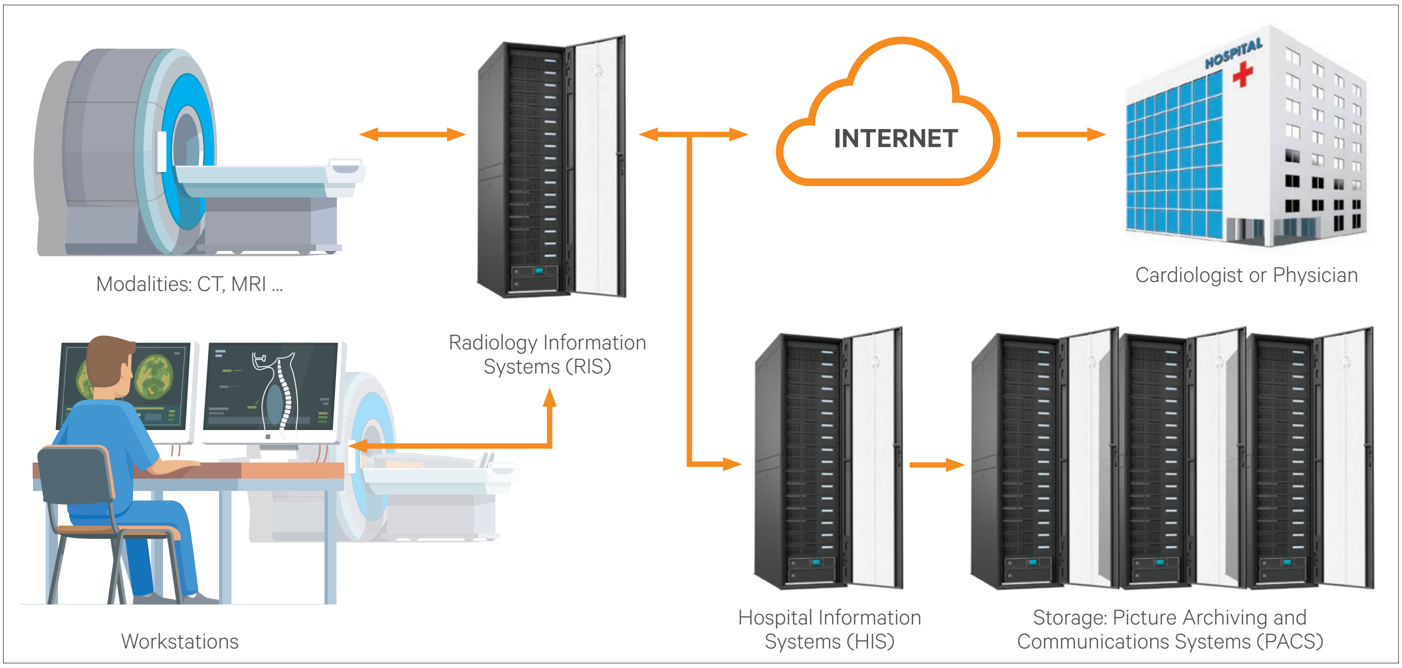

Figure 1. *Typical Medical Imaging & Diagnostic Equipment Network*

the diagnostic imaging files into local servers or within a cloud platform. The main factors which are driving the fast deployment of these technologies are the needs of the healthcare providers to ensure compliance with regulations, control costs, and improve the quality of their services. The backbone of a digital healthcare system is a network made up of different modalities, PACS, RIS/HIS, Computed Radiography (CR)/Digital Radiography (DR), printers and peripherals. This complex network and its components must be compliant with several standards, like DICOM, Health Language Seven (HL7), the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), the Body of European Regulators for Electronic Communications (BEREC), and other national codes such as BS7671:2001 (U.K.), CEI (Italy), and VDE (Germany), as well as the CEI IEC 60364 standard. Across most of Europe, Africa and the Middle East – with the notable exception of Germany and Austria – standard UPS systems must meet IEC standards for electrical equipment in healthcare settings, including critical life support systems. UPS systems are not, however, considered medical devices, which means they are subject to regulations limiting their proximity to patients. A UPS system cannot be connected to a patient and cannot be located within 6 feet of a patient. More relevantly, a UPS system must be installed upstream from the safety transformer. This transformer acts as a boundary between normal building power distribution and distribution for medical equipment. This physical infrastructure must be reliable, scalable, highly available and manageable.

It is composed of:

- **Power systems** such as UPS, Power Distribution Units (PDUs) and isolation transformers and generators to provide uninterrupted, clean power to critical loads
- **Precision cooling systems** that ensure proper environment conditions by adjusting temperature and humidity
- **Racks** that house the critical network equipment like servers, switches and routers, which host critical hospital applications
- **Physical security and fire protection systems**
- **Cabling** to interconnect equipment
- **Management systems** to monitor and manage the infrastructure, locally and remotely to ensure continuous operation
- **Technical services** to install, commission and maintain the systems

The hospital power system is a large and complex electrical network consisting of high voltage transformers, Automatic Transfer Switches (ATS), generators, isolation transformers, PDUs, etc.

This system supplies power to electrical appliances, such as Heating Ventilation Air Conditioning (HVAC) systems, lighting, elevators, pumps, security and safety systems. The nature of these loads, which turn on and off randomly, creates an unstable power environment, creating potential sags and surges that sensitive imaging, diagnostic equipment and other IT devices must sustain. It is highly suggested for healthcare organizations to engage partners like Vertiv with a deep and global engineering expertise to assess the current status and suggest corrective actions.

Diagnostic and Treatment Applications

Modalities

Depending on the patient's disease, physicians can use different modalities for diagnosis and treatment (e.g. X-Ray or CT for orthopedics, ECG or MRI for cardiology, etc.). These modalities can be classified into two categories: **portable and stationary**. Portables can be further

Figure 2. *MRI Device*

classified into hand-held (e.g. blood glucometer) or cart-mounted (e.g. ultrasound) while stationary devices can be further classified into desk-mounted (e.g. blood, urine analysis equipment) or floor-mounted (e.g. CT, MRI). The images in Figure 2 illustrates an MRI device.

In Vitro Diagnostic Laboratories

Clinical diagnostic instruments are used to detect health and disease state markers. Some of the key measurements that diagnostic analyzers are used for are: metabolic markers (blood chemistry), liver function tests, heart disease and heart attack indicators, as well as viral and microbial infections such as HIV or H. pylori.

In Vitro Diagnostics (IVDs) are influencing over 60% of clinical decision-making, while accounting for about only 2% of total healthcare spend. With the development of Personalized Healthcare (PHC), the value of in vitro diagnostic laboratories plays a fundamental role in clinical decision-making, as patients can now benefit from customized treatments based on the analysis of genetic defects or biomarkers in their blood or tissue.
Targeted therapies and diagnostic tests help to improve medical decision-making with clear benefits for patients, while bringing economic advantages to healthcare organizations.

As electrical laboratory equipment may be sensitive to fluctuations in power supply, it is essential to protect all laboratory equipment by providing stable power through UPS. Certain types of equipment often need batteries as back up in case of power failure.

It is important to understand the sensitivity of this equipment to power outages and power spikes as these may affect its lifespan. For both the nature of service that these devices provide and related business model, which is often based on the “pay per result” approach, functionality must be ensured without disruption.

Field Technical Details

Modalities are generally used in an indoor environment. The cart-mounted and desk-mounted modalities generally use 120/208 VAC single-phase with less than 5 kVA of power, while floor-mounted devices typically require 480 VAC three-phase, ranging from 20 kVA to 300 kVA of power.
Floor mount, large imaging systems, such as Angiographers, can create a large power draw while operating under peak demands as high as 400 kW. With increased use of diagnostic equipment in most facilities, this can force system engineers to oversize the power system in order to compensate for these machines, resulting in higher initial costs and reduced efficiencies. Similarly, the addition of new generation diagnostic scanners in a facility may increase the likelihood of a power overload condition, threatening the availability of the entire system or forcing an expensive upgrade. In response to this challenge, Vertiv has worked with medical equipment manufacturers to pioneer the use of UPS systems in peak shaving applications. With this technology, the critical load will be supported by both the utility source as well as the batteries, once it reaches the peak load.

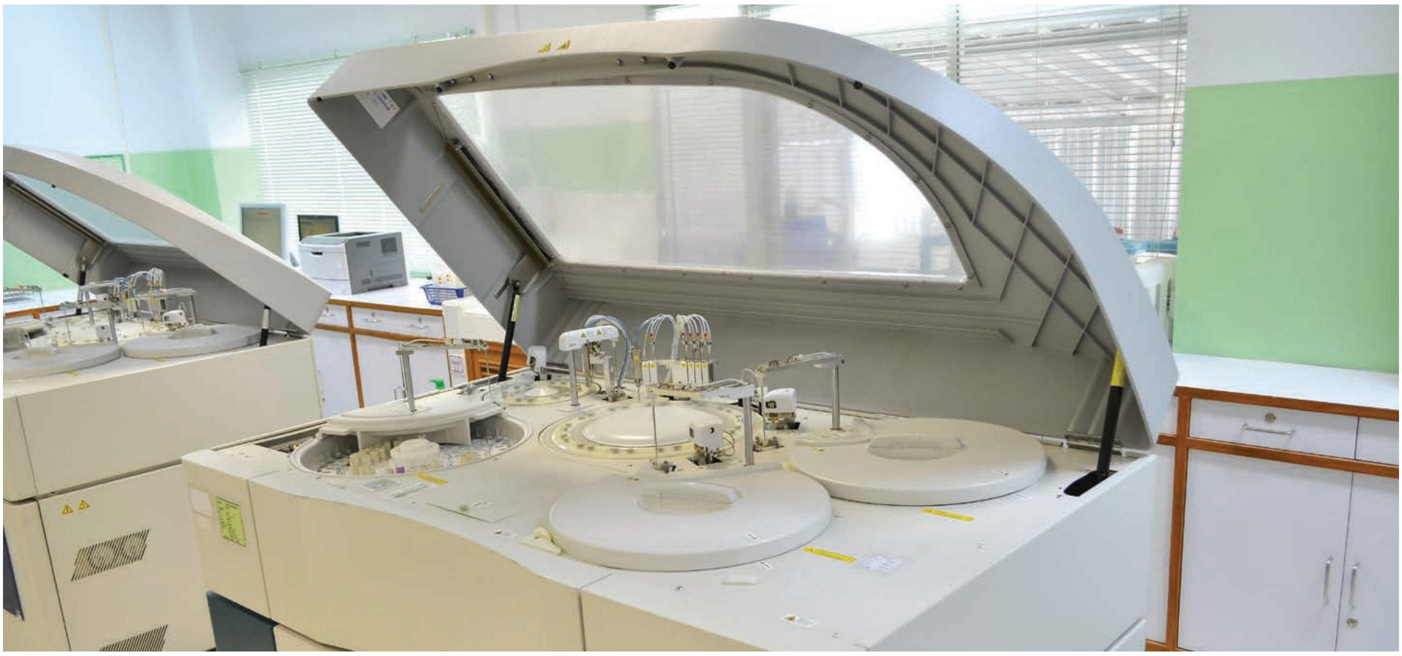

Figure 3. *In Vitro Laboratory*

These peaks typically last less than 20 seconds and can occur sporadically throughout the day, depending upon the nature of the machine. Smart use of dedicated UPS systems upstream from diagnostic equipment allows the network to be sized according to “normal peaks” rather than to extreme conditions created by power-hungry units, ultimately reducing initial costs and improving operating efficiency. In addition, the UPS battery system can be used to protect against outages, as well as peak shaving, depending on how the battery is sized.
In some cases, batteries require space adjacent the UPS. These are often placed in the technical room where all the systems needed to power, cool and control the imaging device are located. This room may be cooled with the building’s comfort air-conditioning system or a precision air conditioning system, which more tightly controls temperature and humidity in the environment. Considering that this room also hosts batteries to provide energy back up to critical equipment, an accurate temperature control is needed. When a hospital's centralized chilled water pipeline is not available in the dedicated technical room, the deployment of a chiller to feed the MRI cooling system must be planned. The average power of this chiller should range from 40 kVA to 70 kVA depending on the imaging system power and whether the chiller is used for other purposes.

Hybrid Operating Theaters

A revolutionary alternative to conventional operating rooms is represented by the hybrid Operating Room (OR), which allows physicians to perform procedures using real-time image guidance and manage perioperative complications, all in a single environment. A hybrid operating room is an operating theater equipped with a large fixed imaging system that supports high-quality interventional imaging as well as complex open procedures and minimally invasive surgeries.
Among the drivers that are pushing the development of such infrastructure, physicians desire to perform new combinations of endovascular, laparoscopic and/or open procedures in the same OR using advanced angiographic image guidance. As new and emerging endovascular procedures are becoming more complex and of high risk, the patient benefits of reduced trauma/faster recovery associated with minimally invasive surgery and interventional procedures. However, there are also challenges facing an implementation of a hybrid OR such as high costs (about $3-4 million on average), implementation time (1-2 years from planning to implementation), space requirements (up to 1,400 square feet, almost twice the size required of a standard OR), staff training and team development.

*The EN 50272-2 standard will soon be replaced by standard EN IEC 62485-2.

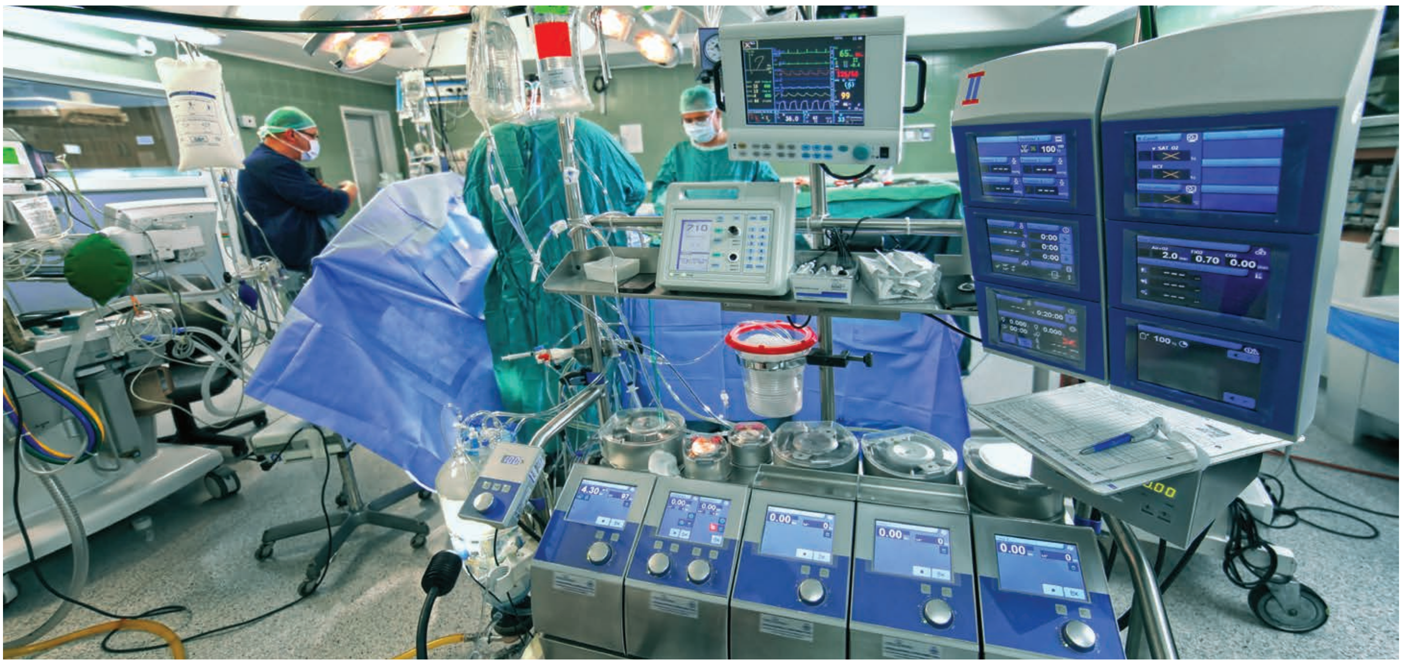

Figure 4. *Hybrid Operating Room*

Technical Recommendations

Since the hospital power grid is electrically "noisy and dirty", with many electrical surges and sags, it is good practice to provide UPS protection to all sensitive, expensive electronic systems.
UPS systems protect hardware, avoid unwarranted system crashes while tests are in progress, prevent loss of patient data files, and provide safe, reliable radiology examinations.

Electrical power systems used in the hospital should meet several standards, including:

- **IEC 60364-7-710:** Electrical installation requirements for medical locations
- **IEC 62040-2:** Electromagnetic compatibility for UPS systems
- **IEEE 1184:** Guide for Batteries for Uninterruptible Power Supply Systems
- **ISO 8528-1:** Standard for gen-set

In Group 2, rooms (medical locations where applied parts are used in applications such as intracardiac procedures, operating theaters and vital treatment where failure of the supply can cause danger to life), the use of unearthed systems (IT*) is a requirement, as an interruption to the power supply is potentially life-threatening to the patients being treated. Treatments cannot be interrupted or repeated and test results need to be saved. The mandatory use of the IT system means the medical electrical devices/systems remain active on a first fault and there is no dangerous increase in the touch voltage. The distribution system should facilitate the automatic changeover from the main distribution system to the electrical safety power source which feeds the essential loads. This automatic changeover device requires a "safe separation" between systems:

- **Luminaires of operating theaters, tables and other essential luminaires** need a power changeover period of <0.5 secs. for a minimum autonomy of 3 hours;
- **Safety lighting, medical electrical equipment in Group 2 medical locations, equipment of medical gas supply, and fire detection** need a power changeover period of <15 secs.;
- **Equipment essential for maintaining hospital services** (i.e. cooling equipment, cooking equipment, sterilization equipment) need a power changeover period of >15 secs.

Depending upon their usage, cart-mounted and desk-mounted devices may require the UPS to comply with the international standard IEC60601-1 for patient vicinity applications. For large floor-mounted modalities, a UPS typically from 50- 300 kVA should be installed to protect the infrastructure. In cases where a large UPS cannot be installed, a smaller one (5-10 kVA), dedicated to the sensitive electronics and computer systems of non life-critical modalities, like CT, MRI, and PET, should also be considered.

***Insulated System IEC 60364-1 and IEC 61557-9 I**: All live parts isolated from earth or with one point connected to earth through an impedance **T**: direct electrical connection of the exposed-conductive parts to earth

As discussed in the "Field Technical Details" paragraph, sizing of the UPS for many devices, such as CTs and MRIs, can be challenging as they draw very high amounts of inrush current, thus great precautions should be taken while sizing their power systems (including UPS, generators, transformers, and switchgear). Their normal power consumption, as well as the inrush current ratings, are available from their modality manufacturers. It is important to allow enough margin for miscellaneous loads and future growth.
Adequate cooling and airflow should be provided for all modalities that have sensitive electronics dissipating heat. For most of the cart and desk-mounted modalities, building HVAC should be sufficient, however, for large floor-mounted modalities like CTs, MRIs, or PETs, supplemental cooling may be required. Precision cooling is preferred as it can provide temperature and humidity control in the CT/MRI room. All of the networked modalities and their physical infrastructure should be monitored and managed (i.e. environmental conditions of the radiology room, UPS battery life, runtime and capacity, and generator fuel) so that anomalies can be quickly detected, and corrective action can be proactively taken to avoid downtime.

Picture Archiving and Communication System (PACS)

Field Technical Details

PACS (Picture Archiving and Communication System) is a healthcare technology for the short and long-term storage, retrieval, management, distribution and presentation of medical images.
A PACS allows a healthcare organization to capture, store, view and share all types of images internally and externally. When deploying a PACS, a healthcare organization must consider the environment in which it will be used and the electronic systems which it will be integrated with.

These systems are made up of a broad range of technologies that enable digital radiology and hospitals to perform teleradiology, telemedicine, and telesurgery. Diagnostic images will be available anytime, anywhere, making their distribution faster, easier, and more reliable. The core of the PACS is made up of storage and server clusters, housed in racks, computers or data center environments. Typically, PACS need less than 10 kVA, single-phase AC power at 120/208 VAC.
PACS need to be available on demand for physicians and specialist surgeons, providing latest imaging data of the patient under treatment. It needs to be available at all times and there is little tolerance for downtime. Since the server clusters are contained within rack enclosures, handling their heat dissipation within the racks often becomes a challenge.

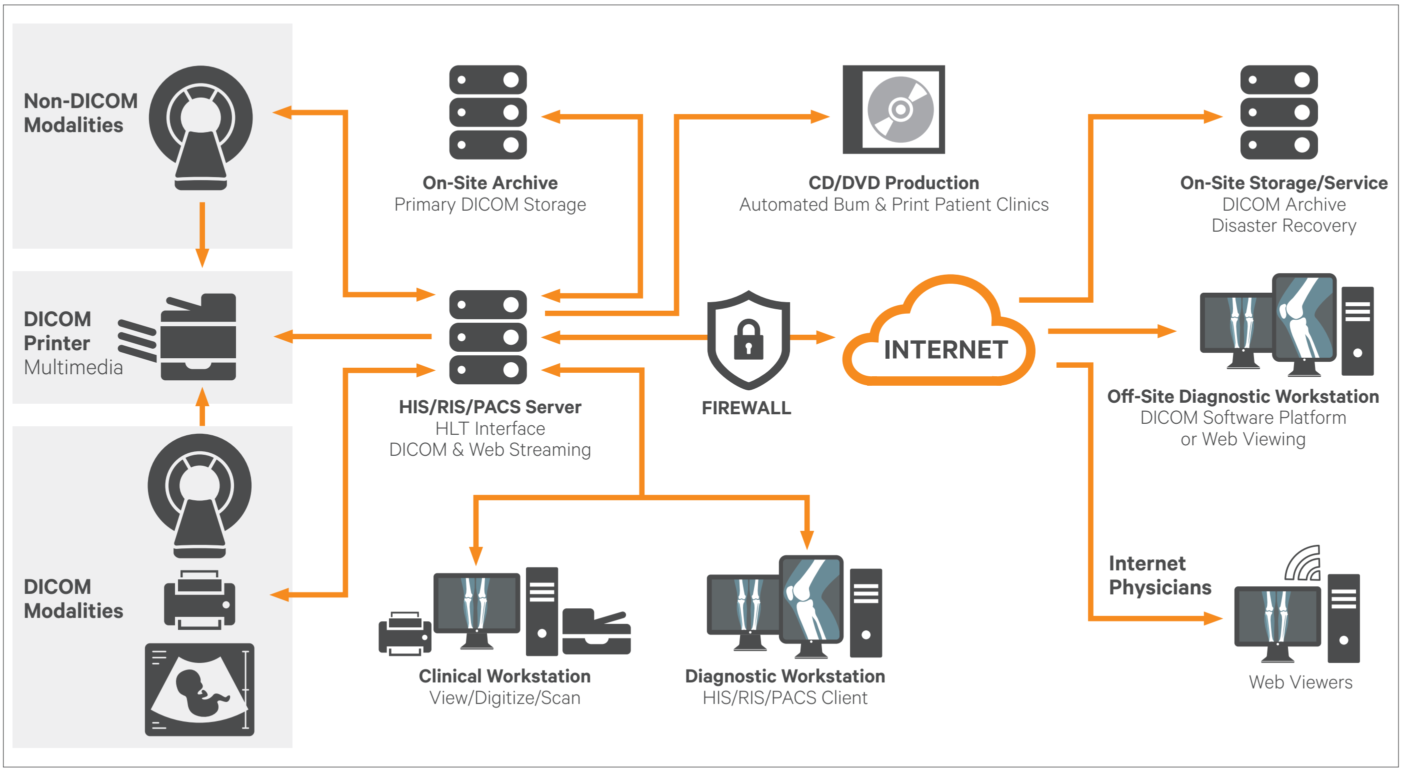

Figure 7. Typical Picture Archiving and Communication System (PACS)

Technical Recommendations

PACS should be protected with an N+1 redundant UPS system which protects hardware and software from malfunctioning, and enables smooth shut downs, rebooting operations if necessary so as to prevent system crashes. For smaller, simpler systems, a basic UPS is sufficient. Considering that, often, additional outlets are needed to plug in all required devices, rack-based PDUs should be used for this scope. PDUs that can measure and display the absorption of current, which can help prevent accidental overloading and enable the PACS shut down, are recommended. For workstations running software applications, UPS protection with smooth shut down and reboot capabilities is recommended. PACS storage and servers should be housed in lockable rack enclosures. Racks housing PACS storage and servers are generally very dense in terms of space and power consumption, and should thus be placed in a temperature-controlled environment.

Moreover, they should also have perforated doors for maximum airflow. When power absorption within the rack exceeds 4 kW, a row-based cooling unit can be used to

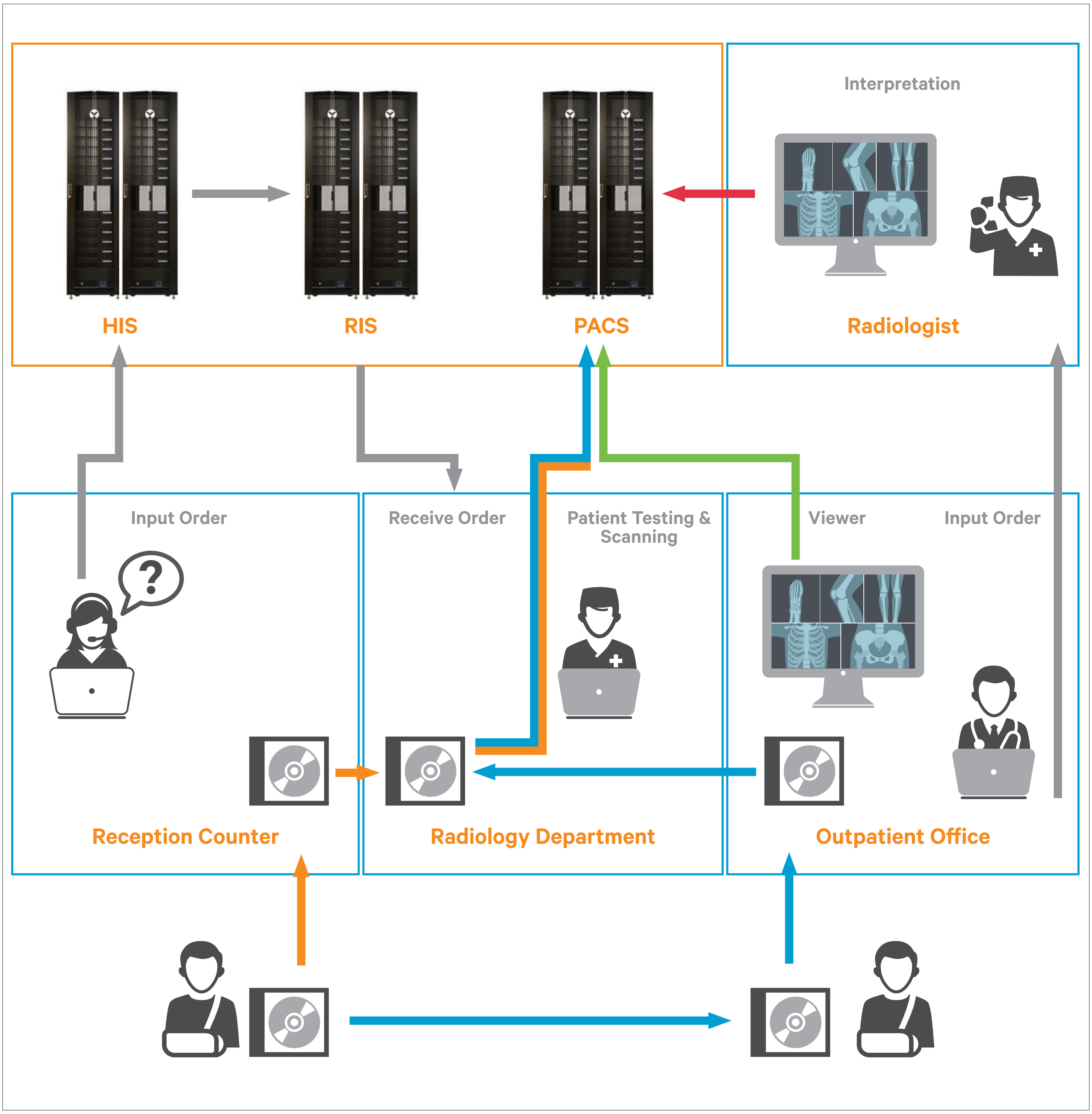

Figure 8. Example of RIS and HIS Server-based Systems

provide supplemental cooling capacity. A good strategy involves the management of PACS servers, storage, and their entire physical infrastructure including UPS, PDUs, batteries and their critical environment (temperature and humidity). This will give early warnings of anomalies or impending disasters so that corrective actions can be taken and shutdowns prevented.

Radiology Information Systems (RIS) and Hospital Information Systems (HIS)

RIS and HIS are server-based systems running special software that make it possible to store, monitor, manage, and distribute patient medical information. They help patients in scheduling appointments, registration and billing, and support hospitals in generating, maintaining, and managing patients' electronic medical records, as well as generating workflows, worklists, management reporting, and a variety of other tasks. These RIS and HIS are becoming one large Hospital Information System and are integrated with PACS as well as various other modalities within the hospitals, providing complete automation. By converting them into "digital hospitals", they can significantly improve patient care, minimizing human errors, saving lives, and reducing costs.

Field Technical Details

These systems are generally housed in a data center environment, absorbing from 10 kW of single-phase 120/208 VAC power to 200 kW three-phase 480 VAC power. Most data centers within hospitals have a UPS with battery back up, precision air conditioning units and a back up generator.

RIS / HIS are the most important systems within the data center, requiring longer runtimes and higher redundancy and availability than most other equipment. Since the entire hospital depends on HIS for normal functionality, its availability requirements are generally 99.999%, which means an average unplanned downtime of 5 minutes per year or less. As for site preparation, attention should be paid to the floor load in terms of weight capacity, elevator capacity and door dimension to ensure that the physical infrastructure, like UPS, batteries, and air conditioning can be transported to their planned positions, as well as proper service maintenance, which should regularly and easily be done.

Technical Recommendations

The physical infrastructure supporting RIS / HIS should provide the highest levels of redundancy while minimizing total cost of ownership. An N+1 redundant UPS with automatic and manual bypass is recommended, and sometimes this redundancy level is extended to the generator and precision air conditioning system to ensure the highest levels of availability. The entire infrastructure should be scalable to allow for future expansion and serviceability to reduce mean time to recover. Higher levels of redundancy, like dual-power feeds with dual generators and dual N+1 UPS with dual power paths all the way to the rack, should be considered for highly critical networks and data centers. PDUs should be able to measure and display current, which can help prevent accidental overloading and shutdown of the RIS / HIS. PDUs that allow remote outlet control via the web are desirable for rapid server rebooting. Isolation transformers should be used wherever required by local laws and precision air conditioning equipment should have the capability of allowing for expansion.

Conclusion

To ensure high availability and reliability to medical imaging and diagnostic equipment, including PACS, RIS, HIS, modalities, and their networks, special attention must be paid to their physical infrastructure. The biggest challenges are power continuity, cooling, physical space, management, and services. Providing UPS protection to all such devices protects hardware, prevents software crashes, and significantly increases their availability.

Cooling is a particular issue for larger floor-mounted modalities, high density storage and servers for PACS, as well as RIS / HIS and hospital wiring closets. In some cases, a building's HVAC system, along with proper ducting, ventilation, and airflow, may be enough. However, in many situations, additional cooling in the form of precision air conditioning is required. Companies like Vertiv have dedicated teams of system engineers who are experts in performing assessments of a data center's physical infrastructure, and can provide detailed reports aimed at improving overall system reliability and availability while minimizing total cost of ownership.

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