BICSI International Standards
Supplemental Information 2

Guide to Medical Grade Wireless Utility

Foreword

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The new paradigm for wireless design in healthcare facilities should include a disciplined design approach. The Medical Grade Wireless Utility (MGWU) brings an engineered process-based approach to wireless network design and implementation.

In every modern building, the common utilities are imbedded into the base plans and designed and structured according to a set of codes, standards and best practices, governed by local code authorities and supported by the building industry. HVAC, electrical and plumbing systems are all designed and structured to deliver cooled and heated air, power and water to the locations in the building where needed to meet the needs of the enterprise and its occupants. Delivery of assured wireless services in a hospital should be no different. However, unlike the other base-building utilities of HVAC, electrical and plumbing, there are no codes and standards for wireless design.

The new paradigm for wireless design in healthcare facilities should include a disciplined design approach. The Medical Grade Wireless Utility (MGWU) brings an engineered process- based approach to wireless network design and implementation.

A hospital's wireless network design is often driven by IT and medical device vendors and increasingly, wireless service providers. As a result, wireless network implementations in hospitals vary dramatically and yield mixed operational results. This legacy procurement model is in need of an overhaul to maximize the operational and cost efficiencies of the network, and to provide consistent quality of patient care and patient safety.

This supplemental information document has been written to provide insight into the need for the MGWU, its design elements and underlying technologies, and implementation considerations.

Healthcare Facilities – Many Buildings in One

A health care facility typically has the characteristics of many building types in a structure, interconnected structures, or a campus of structures. These will vary among facilities, but may include:

- Process environments (operating rooms, treatment rooms including RF free environments)
- Hospitality (patient rooms)
- Laboratories
- Teaching areas
- Public areas
- Office & administrative
- Retail (e.g., gift shop)
- Parking

Many of these areas are shown in Figure 1, which illustrates the first three floors of a healthcare facility.

The communications needs of each user group in these "mini-facilities" will also vary, leading to a multiplicity of networks, with different levels of priority. Increasingly, these communication networks are wireless. This situation argues for thinking of wireless communications as a unique type of "utility" requiring foresight, planning, good design practices, and standards. The benefit of this foresight and planning is the implementation of a wireless infrastructure that doesn't require costly and disruptive above ceiling antenna change management since the broadband antennas are passive.

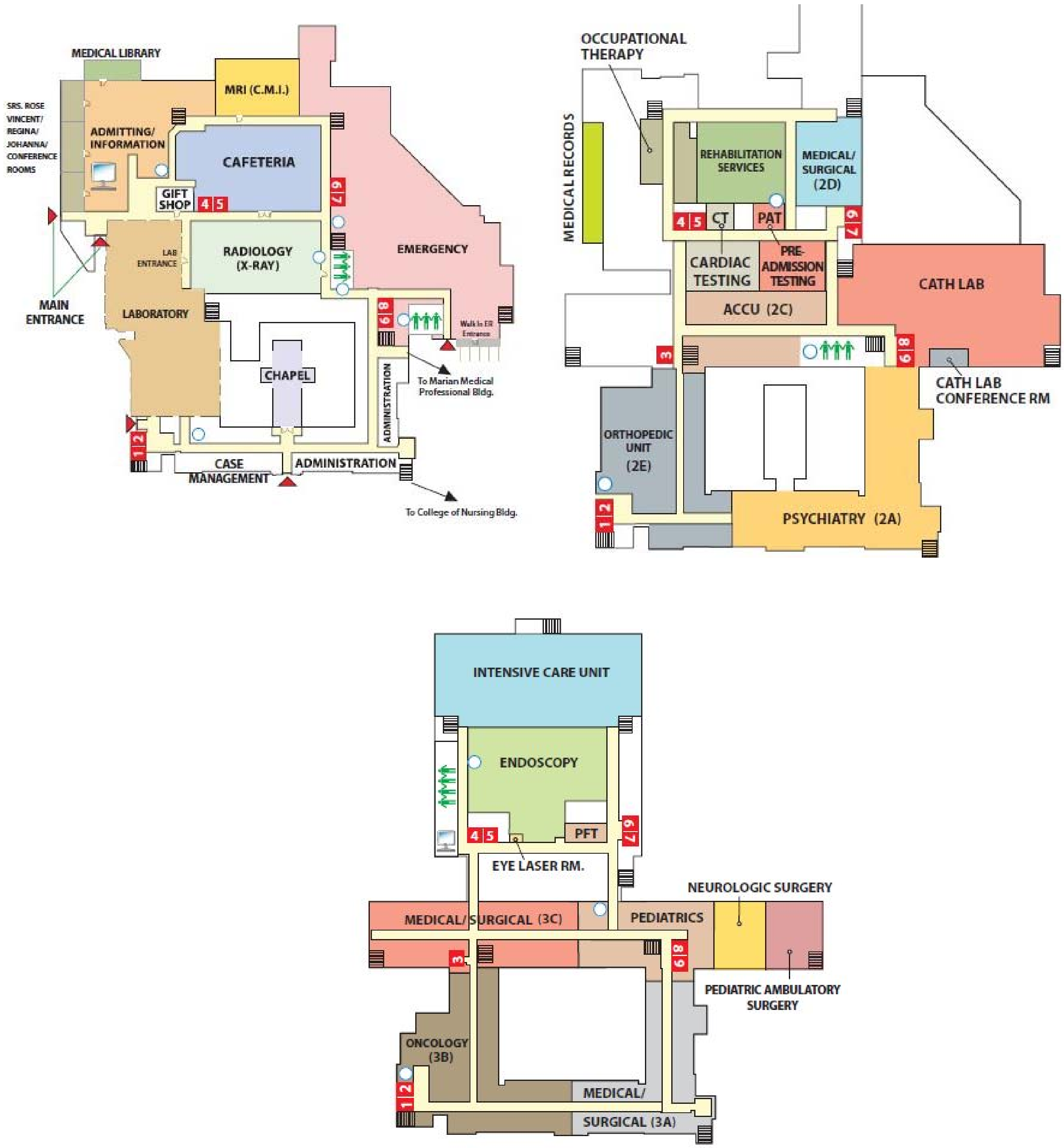


Figure 1 Examples of Different Functional Areas within a Healthcare Facility

Wireless Within the Healthcare Environment

Safely managing wireless infrastructure within hospital walls is a serious challenge due to the explosive growth in consumer and medical wireless devices. This makes it almost impossible for a doctor's tablet (enterprise grade), a patient's smartphone (consumer grade) and a wireless infusion pump (medical grade) to work simultaneously and at a level of assurance required in a medical setting.

The wireless healthcare environment is characterized by inconsistent and widely varying practices, as well as a dearth of design and implementation standards. The hospital setting in particular faces the perfect storm of high growth in user demand for wireless services versus availability of spectrum with assurance. The healthcare community is ill prepared to manage this challenge. Exacerbating growing demand issues are the potential for co-channel interference, device makers' calls for proprietary networks, and a lack of vendor-neutral best practices or standards against which network infrastructure can be installed and measured. These factors contribute to high cost and low network reliability.

The hospital environment is increasingly reliant on both the wireless local area network (WLAN) and the wireless wide area network (WWAN). There has been tremendous growth in healthcare apps, wireless sensors for health monitoring, handheld mobile devices for clinicians, and inpatient wireless medical devices.. The increase in wireless medical devices, coupled with consumer and enterprise use of wireless networks in health care, require a reliable and well-engineered wireless network infrastructure with the assurance necessary to support these needs.

Greater use of other networks does not diminish the need for robust healthcare wireless networks. As such, it is incumbent upon healthcare providers to evolve their approach to deploying and operating wireless networks in order to support this massive growth. Also, over the next several years, a hospital's relationship with Wireless Service Providers (WSPs) will be increasingly crucial as they continue to develop and expand healthcare verticals within their organizations and the FCC approves greater use of the WWAN for medical purposes.

What is Medical Grade Wireless Utility (MGWU)?

The Medical Grade Wireless Utility consists of the cornerstone elements of three grades of service, across four wireless networks which together constitute an infrastructure shaped to the building and engineered to deliver appropriately assured wireless service at the locations in the health care enterprise as required by need.

The MGWU is a vendor-neutral, future-ready wireless infrastructure able to transport wireless signals from medical devices of established vendors and new and startup vendors alike. In addition, it will provide transport for any wireless service provider, paging and two-way radio, and Wi-Fi for guests, patients and the enterprise. Further, a wireless network designed around the principles of the MGWU will provide the critical underpinning for:

- The burgeoning connected health ecosystem, including BYOD (bring your own device) and enabling care out of the hospital
- The increasing importance of the WWAN
- Engineered Wi-Fi
- The increasing use of wireless medical devices as well as location services
- Enabling a higher quality of care and improved patient safety at lower cost to the hospital, and
- A wireless infrastructure that involves no above ceiling modifications requiring infection control procedures.
- Making wireless device decisions based on the infrastructure and not infrastructure decision based on the device.

Grades of Service

MGWU is built upon the premise of three grades of service: Medical, Enterprise and Consumer.

- Medical Grade—LIFE CRITICAL

  Medical Grade Services support clinical devices and applications that exist to collect and share life critical medical information with providers of medical care.
- Enterprise Grade—MISSION CRITICAL

  Enterprise grade services support health devices and applications that collect medical information and are intended to "inform and direct". They are considered mission critical but not life critical.
- Consumer Grade—INFORM

  Generally for use by the public, Consumer Grade wireless service supports consumer devices and applications that make no medical claim and are meant to "inform".

Table 1 provides examples of each grade as applied to healthcare environments

Assurance Measures and Performance

Assurance describes the availability of a wireless network for its intended use. It includes five key components:

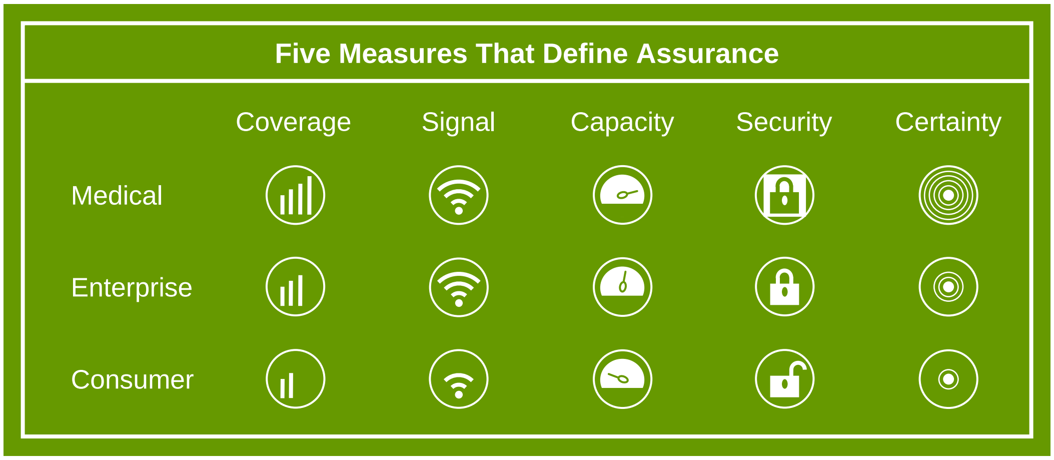
- *Coverage*—The percentage of the clinical space that has acceptable wireless signal and is accomplished by the proper placement of antennas and wireless access points.
- *Signal quality*—Usability of a received signal at a device. Signal quality is comprised of both received signal strength and signal to noise ratio available to the client devices.

  Affecting strength are power, the distance between the antenna and client device, and wireless propagation characteristics. Signal to noise refers to the desired signal in the presence of other wireless protocols.
- *Capacity*—The ability to support a required number of simultaneous users/devices in conducting voice and or data transfers within each coverage area. Capacity is implemented by using some number of radio channels and technologies so that the combination of the channels and technologies are sufficient to support the required traffic.
- *Security*—Physical and cyber protection of the physical components, as well the confidentiality, integrity and availability of RF signals through digital encryption and other means. At the highest level, all communications devices are physically secured to prevent tampering, encryption is WPA2 or equivalent and equipment is compatible with the facility's authentication server(s).
- *Certainty*—The ability of a protocol to operate in an associated RF environment and to deliver the required communications performance, as defined by relevant parameters (throughput, latency, jitter), without impact to other applications/devices.

The three grades of service are differentiated by their assurance requirements, with medical grade being the most stringent, as portrayed in Figure 2.

Table 1: Example of Applied MGWU Service Grades

Medical	Life-critical, clinical patient care devices like wireless medical monitoring and telemetry systems, infusion pumps and future technologies such as MBAN (Mobile Body Area Network) devices and diagnostics
Enterprise	Physician and nurse-deployed work stations, smart phones and tablets for secure wireless access to electronic health records, nurse call systems, asset management and first-responder communications
Consumer	Shared guest Internet access for consumer devices like cellular phones, tablets and laptop computers



	Coverage	Signal	Capacity	Security	Certainty
Medical	100%	100%	100%	Maximum	100%
Enterprise	95%	95%	95%	High	95%
Consumer	90%	90%	Best Effort	Limited	90%

Figure 2 Service Assurance Requirements

Wireless Networks

Wireless Clinical Data Network (WCDN)

The WCDN is a logical network that uses the physical assets of the broadband (DAS), WLAN and possibly other networks to carry its traffic. It includes both licensed and unlicensed radio frequency bands and is used for medical devices providing life critical continuous monitoring. Such devices could include patient monitoring, telemetry, and infusion pumps. As such, the WCDN requires a Medical Grade of service.

Wireless Local Area Network (WLAN)

The WLAN is a physical network which includes the use of unlicensed frequencies in a manner that is intended to be used within the facility and adjacent grounds. WLAN services may include Wi-Fi 802.11, Zigbee, USB, or other future technologies and depending on the client device, could require consumer, enterprise or medical grades of service.

NOTE: Wi-Fi is a trademarked term meaning IEEE 802.11x wireless transmission for network or Internet connections. The medical 802.11 network supports data, voice, and video across clinical, enterprise and consumer applications and devices.

A layered Wi-Fi architecture is a key element of the Medical Grade Wireless Utility. This architecture enables dedicated channel use for specific Wi-Fi enabled services (those with similar traffic types) and is critically important to the healthcare wireless environment, especially in the transmission of wireless signals from Class III medical devices.

A layered Wi-Fi architecture will assign a selected subset of the total Service Set Identifiers (SSID's) to each of three Access Points (with limited overlap of such subsets) such that the traffic is separated by application type and or device type and/or protocol to enable separation (and to prevent interaction) of medical, enterprise, and consumer grade networks.

The key principals of unified wireless network architecture are scalability, roaming, mobility, manageability, and security.

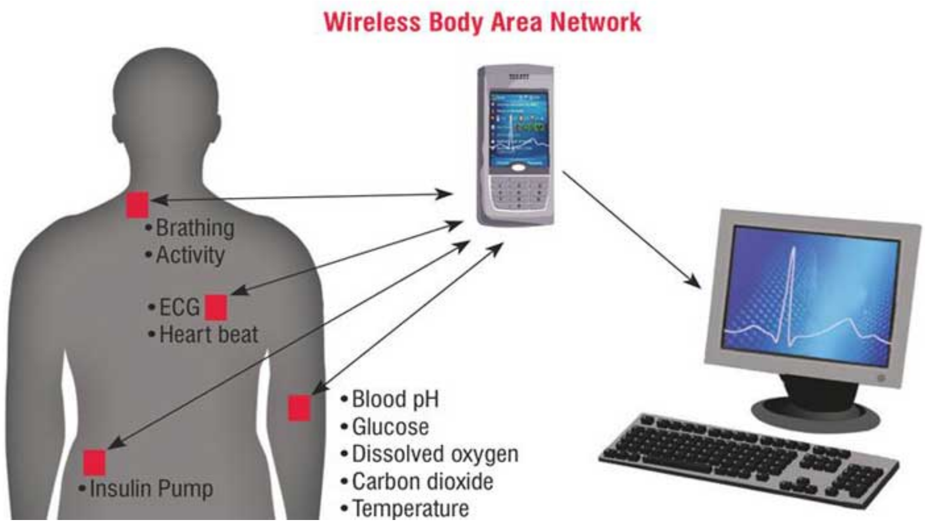


Figure 3 Illustration of a Wireless Body Area Network (Part of the Wireless Clinical Data Network)

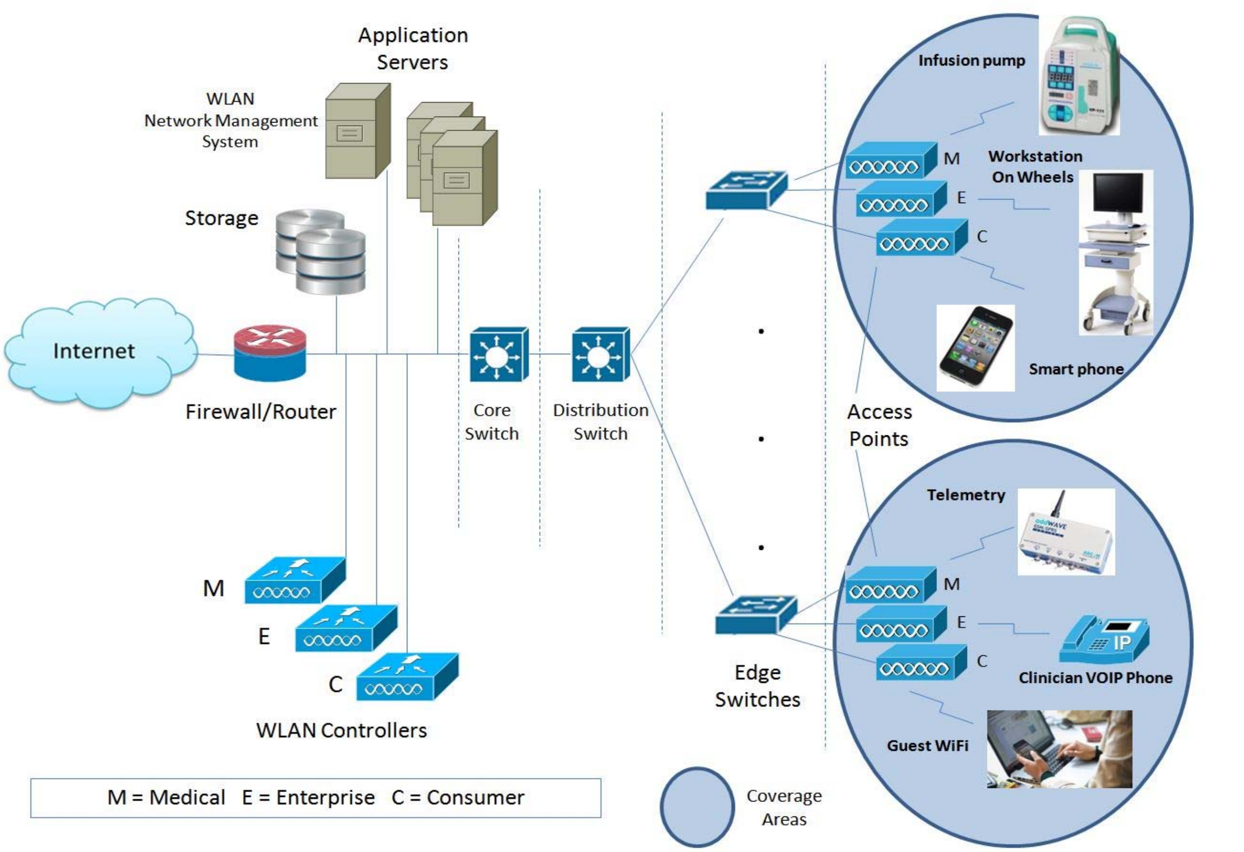


Figure 4 Illustration of Layered Wi-Fi

Wireless Wide Area Network

The WWAN is a physical network which includes those wireless services that are intended to work both inside and outside the facility. Services could include cellular, paging, life safety radio, and two-way radio and as such requires a consumer or enterprise grade of service at this time. Cellular service includes a variety of frequency bands and different generations of protocols and technologies such as 2G, 3G, and the LTE implementation of 4G.

Location Local Area Network (LLAN)

Like the WCDN, the LLAN is a logical network that uses the physical assets of the other networks and technologies for its traffic. It is used to locate people and assets within the grounds of the facility. Assets used could include 802.11, Zigbee, infrared, ultrasound, RFID, and UWB. The LLAN require an enterprise grade of service.

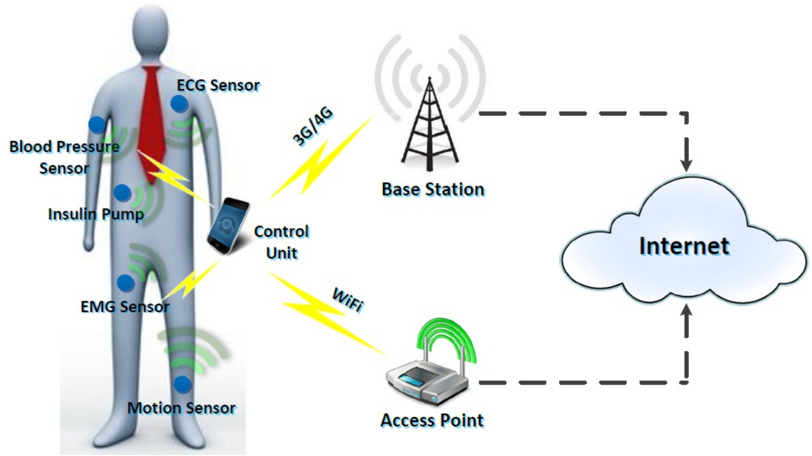


Figure 5 Example of a Wireless Wide Area Network Healthcare Application

IMPLEMENTATION

Design Challenges

The medical facility may be a complex ecosystem with multiple types of users, functional areas and departments, and myriad wireless services that range from legacy wireless deployments to new implementations which may employ emerging technologies.

Structural Environment

Complicating the ability of the hospital operator to deploy robust wireless infrastructure throughout the facility are differences in construction methods and materials from that of most other buildings. Due to constant occupancy and equipment loads, the hospital building must be of sufficient structural strength to support this loading from the people it takes to run the enterprise, patients and visitors as well as the systems and building materials required. Some examples of this system and material density are medical gas distribution networks, completely ducted HVAC supply and return in many areas, rated fire walls with smoke compartments, separate exhaust systems for many rooms, as well as rooms requiring lined walls where X-ray, MRI or CAT Scan are carried out. These factors all contribute to the need for greater size and strength of structural steel, thicker floor slabs, and thicker walls inside hospitals. In older buildings, terra cotta block and lathe also contribute to the challenge to wireless designers in providing networks that will provide effective coverage for the healthcare enterprise.

Further, hospital construction above the ceiling is a system-dense environment with mechanical, medical gas distribution, ventilation, and chilled water plumbing all contributing to the complexity of planning a wireless network.

Smoke compartments, fire rated walls with multiple layers of sheetrock, sprinkler systems, and lead lined rooms add further complication to wireless design.

Electrical Environment

The electrical power needs of hospitals are greater than most other typically sized buildings and may be thought of in industrial terms. Patient support systems, diagnostic equipment, 24/7/365 building usage and patient amenities and requirements all combine to create a significant electrical load. This impacts the wireless scenario in several ways. The electromagnetic environment is the complex result of the many varied electrical systems in the facility. Power is more robust with the requirement for standby emergency generators. As IT and wireless communications systems expand, so too grows the need for additional emergency backup.

Area Specific Requirements

The multi-dimensional usage requirements of a medical facility create a variety of different design and implementation considerations not encountered in non-medical buildings. These include:

- Office and Patient Areas: (resemblance to office buildings)
  - Impact of Low-E glass
  - Varying “tenant” requirements
  - Restriction of certain networks, devices and antennas
  - Age of building and presence of hazardous building materials
  - Use of metal in walls, window frames, and door opening
  - Telecommunications, data, and security requirements
- Diagnostic equipment and operating areas (resemblance to industrial)
  - High voltage
  - Extensive shielding
  - EMI/RFI
  - Hazardous/flammable substances
  - Controlled substances
  - Security
- Teaching areas
  - Restrictions on use of personal communications devices
  - Varying needs for telecommunications services, e.g. streaming video
- Reception, hospitality and food service areas
  - Greater exposure to general public
  - Expanded use of personal communications services
  - Entertainment systems
  - Point of sale systems
- Parking structures
  - Unique structural characteristics
  - High density of metal objects (vehicles)
  - Likely greater exposure of MEP services
  - Security requirements

Each of these areas will likely have its own unique EMI/RFI environment and require different types of wireless services and grades of service.

NOTE: While it is impractical to extend Medical Grade Wireless Utility to an entire parking garage there is a growing trend to provision an area of the structured parking for basic wireless communications for triage in the event of a natural disaster or other situation where large numbers of patients are transported to the facility in a very short period of time. This provisioning would generally include the WWAN and an enterprise grade layer for the WLAN that will provide basic wireless communications for the designated area of the parking structure.

Cross Functional Team

Due to importance of the wireless infrastructure and the number of departments and people it touches in the hospital, Cross Functional Teams are critical to the success of the planning and execution of the MGWU implementation. Cross functional teams may consist of multiple sub-committees and should include representatives from the following departments:

- IS/IT department
- Biomedical Engineering
- Facilities Dept.
- Clinical representative
- Security

The recommended approach is to assemble a MGWU steering committee composed of one or more members of the above listed departments. Engagement is important from all constituencies inside the hospital that will touch the wireless network.

A MGWU Service Provider Sub-Committee should be initiated to deal with services deployed on the WWAN, including Two Way Radio, First Responder, Paging and PCS/Cellular. One of the more important elements of this sub-committee will be developing strategies to deal with the WSPs (Wireless Service Providers). This will be a very important relationship for the hospital due to the growing importance of the Wide Area Network and the interest of the WSPs in the healthcare vertical market. Since hospitals are gathering points for WSP customers, effective coverage inside the hospital is a key consideration. The hospital should plan to include at least two cellular carriers in the hospital to foster competition and to provide effective cellular networks for their employees, guests and patient. The sub-committee should be ready to work with the WSPs to identify the potential financial contribution or equipment each will contribute to the implementation of the MGWU.

Planning

The planning phase of the MGWU is critical and a number of considerations should be covered while planning the implementation. These may be different, depending on whether the MGWU is to be deployed in new construction or as a retrofit to existing space. For example, retrofit may come with a price premium due to the additional difficulties of working in a functioning medical enterprise with care providers and patients, implementation of infection control methods and the like.

Infrastructure—Whether new construction or retrofit, the owner should work with the design team to reserve space and design a wireless telecom room (which could be combined with a traditional IDF or MDF). They will also need to plan for power (including backup power considerations), cooling and physical security requirements for the room.

WWAN—Special considerations that need to be planned for early in the process are backhaul and the signal source for the WWAN interface with the MGWU. Both the owner and design team should begin planning with the WSPs early in the process to provision for a signal source to the building site. The cost of the signal source will vary depending on the size of the hospital, the needs of the individual wireless service provider and other considerations, but the hospital should consider, during the process of negotiating with the WSPs, the extent to which they will benefit from the inclusion of their wireless network inside the hospital.

Design Team—MGWU planning should include contracting with a wireless designer and system integrator (who are both important in the design process) as early as possible. Due to the complexity of the implementation and large number of internal and external stakeholders, the design team will be instrumental in planning the system and working with the external stakeholders such as device and IT equipment manufacturers and wireless service providers to insure the project meets its objectives.

Antenna Placement—Broadband antennas can be placed above or below a hard ceiling or lay in tile. Either scenario works and is up to the facility. Above ceiling placement is out of sight and reduces the possibility of tampering, but may experience some signal loss due to the ceiling material. The proper system engineering will mitigate this possibility. Since MGWU contemplates the use of passive broadband antennas and consume no power, above ceiling installation will not cause infection control events. If space above the ceiling is inadequate, below ceiling installation is a better alternative. Since Wi-Fi access points are power consuming, they should be installed in a cabinet flush with or below the ceiling, or wall mounted. The design team should address antenna mounting considerations in their detailed design.

Once the design team is selected, they will begin the design process using a variety of tools.

An RF Site Survey is necessary for either new construction or retrofit projects to benchmark the existing levels of RF in spectrums to be used inside the hospital. The survey will include Band Scans and Carrier RF Level Tests which will test the WWAN for available channels, signal levels, capacity, signal to noise ratio, data throughput and voice quality.

The design team must use an in-building wireless network design software tool that will enable detailed design based on existing or projected building materials and in-wall/ceiling system density. This pre-construction design capability will enable specific planning on a per spectrum basis. It also protects both parties (wireless designer, Integrator and owner) in the event that materials or systems are changed during construction. Actual wireless coverage will be measured against the detailed design during the test phase of the project.

Implementation Testing

Upon completion of the Medical Grade Wireless Utility implementation the RF signal performance should be tested by the system integrator. The cable infrastructure should be tested by the installer at the time of each cable's installation.

All cable that is installed to support the MGWU should be tested, including fiber optic, category rated and coaxial cable. The cable installer should use an ODTR to test fiber optic cable, a cable analyzer for the copper category rated cable plant, and a RF DTF to test coaxial cable. Cables should be tested for signal attenuation and faults. RF cabling should be tested for VSWR and DTF. In cases where the total composite RF power within a cable exceeds 1 Watt, PIM testing is required. The cable installer should provide a written report of results for these tests to the owner upon completion.

In addition to the cable testing, an RF integrity test should be completed by the system integrator for both the broadband and Wi-Fi networks. Wi-Fi testing should be done by walk testing the facility with an appropriate portable Wi-Fi Analyzer (like AirMagnet). Testing should confirm that Wi-Fi coverage meets the requirements as specified during planning and in pre-construction documents. Testing should also illustrate the presence of enterprise APs, any rogue or unexpected APs and other noise in the building that affects the efficiency of the Wi-Fi network.

Broadband integrity and acceptance testing should also be performed and done in coordination with the Wireless Service Providers (whose signal is being broadcast in the hospital) and the Authority Having Jurisdiction.

Broadband signals should be walk tested and compared to the preconstruction projections. Acceptance testing is then performed to mimic the prescribed carrier (WSP) RF levels. A WSP approved multi-band scanning receiver (like PCTEL SeeGull MX), should be used for spectrum testing. A written report of results should be provided to the owner as well as a document that shows the walking path taken while testing to ensure total coverage and testing of the required areas within the project.

Summary

When effectively planned and designed, a hospital can embed a wireless infrastructure in its buildings that effectively delivers wireless to any area of the building or campus based on need. Wireless becomes the fourth “utility” in the building at a fraction of the cost of the other base building utilities (mechanical, electrical and plumbing) and is delivered with the assurance required by the application and grade of service.

Design and implementation of the Medical Grade Wireless Utility is a process that takes thought, engagement across hospital departments, and a desire to implement an effective wireless infrastructure. MGWU can prepare the hospital for the changing healthcare IT environment, future wireless technologies and enable a mobile care model inside the hospital. It will add to the efficiency of clinicians and employees across the enterprise.

Case Study

Vision, Communication, Teamwork, Planning…

All of these were in abundance 10 years ago when a comprehensive community hospital in New England concluded that the key to providing consistent high quality healthcare meant moving aggressively into electronic medical records which could be instantaneously shared. The Vice President of Corporate Facilities and Support Services, Chief Information officer, clinical engineering, physicians and other key stakeholders met to consider how they could enhance the quality and effectiveness of their 900,000 ft^2 (83,600 m^2), 150-bed, multi-building facility. The age of structures on the campus dated from 1900 to 2010, and each presented its own technical challenges. Long before the Affordable Care Act, they determined that an electronic medical record was a certainty. The team knew wireless connectivity was a prerequisite for physicians and clinical staff to access systems that optimize care, and promote expedient healing. At the same time wireless medical devices and systems were beginning to proliferate. The team saw the need to tie patient data, record sharing, voice communication, and other services together somehow, but they faced the dilemma of every service having their own antenna system, spotty and variable coverage areas, and the inevitable support requirements. A future which involved multiple parallel systems, constant addition and moving of antennas, and continuous disruption was simply unworkable and unacceptable. There had to be a better way to deploy a wireless infrastructure.

Through research, a communications services company founded by defense industry veterans was identified which had an antenna solution that could accommodate multiple systems. In the words of the hospital's Vice President, the firm completed "*a phenomenal engineering study of the campus and designed a system with no dead spots… basement, roof, ICU, you name it.*" (In the eight years of system operation since, not a single antenna has had to be relocated, even though 25 – 30 additional wireless devices and systems have been added to the original infrastructure.) The system was carefully engineered to optimize performance of the antenna system, a key element of which was thoughtful frequency management. Services were prioritized to allow the more critical functions to operate at the most suitable frequencies. New services added to the system were done so only after analyzing their frequency effects upon the system, and, if necessary, changing the transmitting equipment's frequency. Services include patient monitoring, VOIP phones, 2-way radio, public safety radio and cellular from three different carriers who enjoy coverage throughout the facility. This is in addition to guest and enterprise Wi-Fi, infusion pumps and EKG. Thousands of devices now transport signals across the wireless infrastructure. The full implementation of the system covering planning, materials, installation, commissioning and expenses associated with temporary patient relocation totaled approximately $1 million USD when completed.

The combination of electronic medical records and computerized physician order entry now being 100% electronic with a robust wireless infrastructure has yielded numerous benefits. As anticipated, the consistency and quality of care has improved dramatically. Since there are no dead spots in coverage, there is no disruption to patients or critical areas due to the need to add or reposition antennas. Also, emergency messages can be received anywhere in the facility and acted upon in a timely fashion. Doctor, staff, and patient satisfaction are high. The immediate sharing of patient information, including test results, has increased efficiency and response times.

Without knowing it at the time, this hospital created one of the first Medical Grade Wireless Utilities—because it just made sense.

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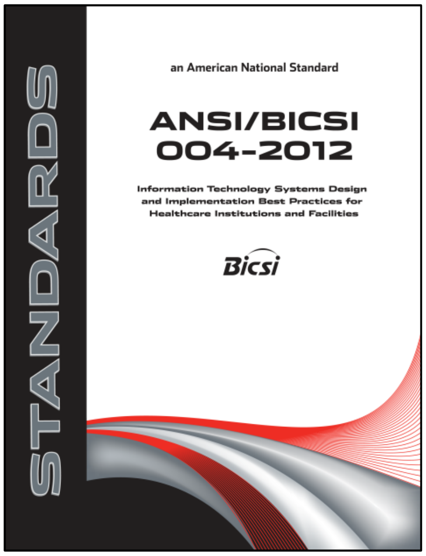
Additional Resources From BICSI

ANSI/BICSI 004-2012

Information Technology Systems Design and Implementation Best Practices for Healthcare Institutions and Facilities



To aid today's designer, ANSI/BICSI 004-2012, Information Technology Systems Design and Implementation Best Practices for Healthcare Institutions and Facilities, was created to provide guidance on the issues specific to the healthcare environment. Written for the wide variety of facilities including hospitals, outpatient clinics and skilled nursing facilities, this standard covers not only common telecommunication and IT infrastructure concerns, but specific healthcare systems such as nurse call, interactive television/hospitality systems and connected medical imaging.

ANSI/BICSI 006-2015

Distributed Antenna System (DAS) Design and Implementation Best Practices

ANSI/BICSI 006-2015 is the first DAS infrastructure standard that provides designers and installers both information on the types and components of a DAS and also provides requirements and recommendations for the design and installation of a standards-compliant, vendor-neutral DAS that is able to be used for a wide range of applications, environments and locations.

Learn more about BICSI 004 and BICSI 006 and view the first five sections of each for free at www.bicsi.org/004 and www.bicsi.org/006

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