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Article

Considerations for the effective management of LANs in hospital buildings

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Abstract: According to a joint survey conducted by the Ministry of Internal Affairs and Communications and the Ministry of Health, Labour, and Welfare of Japan, over 90% of Japanese hospitals have introduced wireless LAN. However, about half of the hospitals that have wireless LANs have reported having experienced problems, with the most common cause being inappropriate management of signal propagation. Other factors include an excessive number of terminals connected to one AP, an information load that approaches or exceeds the limits of the network's capacity, and a lack of information sharing during design and construction. There is also a move towards converting in-hospital PHS, which has been used mainly for nurse calls, to smartphones, which also provide voice communication over a wireless LAN. Furthermore, the number of medical devices with wireless LAN communication functions is increasing. In recent years, issues have emerged regarding the coexistence of wireless LANs used by patients. This includes security aspects, as with problematic operation of wireless LANs. The above could become even more significant considerations in future wireless LAN utilization. In this paper, we summarize issues we have identified, clarify their causes, and present possible future problems and current and future measures to be taken for their solution.

Keywords: hospital construction; in-hospital LAN; wireless communication; LAN cabling; network management

1. Introduction

According to a joint survey (FY2020) conducted by the Ministry of Internal Affairs and Communications (MIC) and the Ministry of Health, Labour, and Welfare (MHLW) of Japan, over 90% of Japanese hospitals have introduced wireless LAN [1]. According to the same survey, about half of these hospitals have experienced problems. The most frequently cited causes are 'poor signal reception in certain locations' and 'slow transmission rate or premature disconnection of wireless LAN.' These include signals that do not reach the terminal from the access point (AP) or reach it with less than the required strength. Other factors related to 'slow communication speed' are an excessive number of terminals connected to one AP, an information load that approaches or exceeds the limits of the network's capacity, and a lack of information sharing during design and construction. There is also a move towards converting in-hospital PHS [2], a Japanese technology that has in the past been the main system for nurse calls, to smartphones, which also provide voice communication over a wireless LAN. Furthermore, the number of medical devices with wireless LAN communication functions is also increasing. In recent years, issues have emerged regarding the coexistence of wireless LANs used by patients. This includes security aspects, as with problematic operation of wireless LANs. The above could become even more

significant when considering the future of wireless LAN utilization. In this paper, we summarize issues we have identified, clarify their causes, and present possible future problems and current and future measures to be taken for their solution.

2. Current status of and problems with in-hospital LAN

2.1. Typical in-hospital LAN

The typical configuration of a hospital LAN must support the diverse needs of healthcare delivery while ensuring reliability and security. In large hospitals, they are also designed to prioritize seamless communication between hospital departments and functions. **Figure 1** shows a typical in-hospital LAN structure.

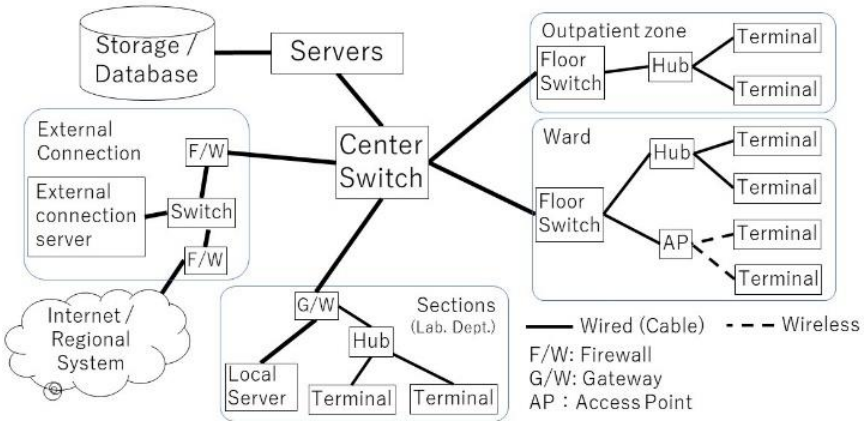

Figure 1. A typical configuration of an in-hospital LAN [3].

As depicted in **Figure 1**, most hospital LAN are cable-based systems in which the Hospital Information System (HIS) server is connected to a wired LAN. Unshielded twisted pair cable (UTP cable) is often used to connect the servers to local routers and to routers at various locations throughout the hospital. Fiber optic cable is sometimes used. Along with the wired infrastructure, hospitals often incorporate wireless LAN (Wi-Fi) technology for communication between access points (APs) and mobile devices such as laptops, tablets, and smartphones used by the medical staff, patients, and visitors. Departments such as radiology and clinical laboratories that use and store large amounts of data (images, EEG and other waveforms) that are only used within the hospital can reduce the amount of data flowing through the hospital LAN by using a gateway system to separate it from the hospital LAN. Because of the sensitive nature of medical data, security is the most important consideration, not only for data but also in the configuration of the hospital LAN. Hospitals must protect patient information and prevent unauthorized access and data leakage by implementing robust security measures such as firewall systems. To ensure continuous operation and data integrity, hospital LANs incorporate redundancy and backup mechanisms. This includes redundant network links, backup power supplies, data backup systems, and disaster recovery plans to mitigate the effects of network failures and interruptions.

2.2. Problems with hospital wireless LAN

- Inappropriate signal reachable area management through the use of appropriate construction materials

As indicated above, there are reports of problems with wireless LANs in which "signals emitted by the AP do not reach the terminal with sufficient strength." This can reduce the transfer rate between an AP and a terminal or cause communication to be interrupted. This type of problem often occurs because the distance between the AP and the terminal is further than expected or because a metal product (door, wall, fixture, etc.) or other obstruction (e.g., metal fixtures) is placed between the AP and the terminal. Factors that can lead to this happening include the architect providing too little information on the materials used in the building, improper estimation of the terminal range, and improper settings for roaming.

- Existence of electromagnetic noise

Interference by electromagnetic fields that various devices, including specialized medical devices, emit or leak can be problematic, especially with wireless LANs using the 2.4 GHz band. Electromagnetic fields in this frequency band are used as the ISM band and in microwave ovens and microwave therapy devices.

Electromagnetic noise has also been observed on the 5 GHz band. From the viewpoint of managing wireless LAN, because radar signals are protected by Dynamic Frequency Selection (DFS), they will be treated as electromagnetic noise.

2.3. Issues with hospital cable LAN

Hospital cable LANs face numerous challenges, from inadequate management practices to infrastructure vulnerabilities. These issues manifest in various forms, including inadequate network apparatus management, electricity failures on network equipment, and inappropriate cable management. Each of these challenges poses significant obstacles to the reliability and performance of hospital LANs, impacting critical communication and data exchange processes.

- Inadequate Management of Network Apparatus:

The routers, hubs, and cables in wired LANs, prevalent in most hospital networks, often suffer from inadequate management. Recognized problems include:

- Electricity failure on network apparatus

If a router or hub loses power, communication between terminals and servers is interrupted, even if there are no problems in other parts of the system. When this happens, it appears to the user as if the entire system has stopped.

- Inappropriate cable management

LAN cables are rarely replaced once installed. Hospitals with inpatients are open 24 hours a day, so cable renewal is rarely done except during major building renovations. The wireless LAN on the terminal side may be faster than needed for the transfer, but the upper limit of the transfer rate between the terminal and the server depends on the UTP cable itself. Category 6A UTP cables, which are often used as LAN cable for terminals, have a capacity of 10 Gbps. This is much lower than that of the newest wireless LAN standard, 46 Gbps in IEEE802.11be [4].

3. Problems related to in-hospital LAN at various stages of hospital construction

Some of the factors contributing to the problems described above derive from the construction process. When constructing a hospital, the larger the scale the more complicated the procedures and processes become. The process starts with the design, followed by construction of the foundation then the frame of the building. The interior infrastructure is then added, such as air conditioning, electricity, water supply, drainage, and communications systems, followed by placement of the interior fixtures and finally installation of medical and medical support equipment. Design is of two types: the basic design and a final detailed design. In most cases, the delivery of equipment is done after completion of the interior and inspections based on the Building Standards Law, fire department inspection, and health department confirmation.

Much depends on the number of floors of the hospital building. In the case of mid- and high-rise buildings, each process is contracted separately, and they do not proceed in parallel. The framing work on the upper floors may be ongoing while the interior work is being done on the already framed lower floors. In addition, the design of the location of some rooms or the purpose of room usage may change frequently, mainly at the request of the hospital. In addition, the distinction between “equipment” and “fixtures” can be confusing in Japan, especially in the area of information and communication technology (ICT). For example, nurse call systems are categorized as part of the “interior infrastructure” because they are similar to telephones, while LANs (including wireless LANs) are often treated as “equipment.” In any case, when the installation of ICT equipment is carried out, the construction of the building frame and the interior work may already have been completed.

The biggest problem with this kind of construction procedure is that there is too little sharing of information among persons involved in these stages. Even when information is shared, it is often only in the form of simple drawings. In some cases, design changes that occur in hospital wards during the construction process are not properly shared. As a result, necessary information about the material of walls, doors, and floors is not properly communicated. Sometimes the correct location of the antennas cannot be determined due to a lack of information in the design. This also includes a lack of information about radio wave propagation. As a result, it is impossible to simulate correct electromagnetic wave propagation, which in turn causes problems with knowing the actual propagation. In many cases, hospital staff are not allowed to enter the building until after the completion of the inspections. This is problematic because it is difficult to determine if the location of the antennas is correct just by looking at the architectural drawings.

Care must also be taken when a hospital building is renovated. For example, when a multi-bed room is converted to a private room, a new wall is inserted. If the use of a room changes as a result of a major renovation, the new wall material may be different than that of the original and radio wave propagation may change depending on the materials used in these new walls.

4. Future considerations for in-hospital LAN

Problems that may occur with in-hospital LANs after the initial installation.

(1) Confusion caused by inconsistent wireless LAN standards used by medical devices.

The use of medical devices with wireless LAN communication functions is increasing. Some of these, such as medical pumps, do not state in the accompanying documentation the name of the wireless LAN standard used. The technical conformity mark attached to the device case at least gives an indication of the frequency band used, and many use the 2.4 GHz band (e.g., IEEE802.11g). On the other hand, mobile radiography equipment (so-called 'portable radiography equipment') often uses the 5 GHz band (e.g., IEEE802.11a) between the digital tube board and the equipment and between the equipment and the image database (Picture Archive and Communication Systems, PACS). We did a web-based study to see if the name of the wireless LAN standard could be found on the Web or linked to the files of various medical items: 8 pumps and 3 pieces of mobile radiography equipment. We found the standard on only 1 pump and 1 piece of mobile radiography equipment. To include the standard name used by a device using wireless LAN on its web catalog and its attached document is not currently mandatory for Japanese medical devices. Although it may be in the device's paper catalog or user's manual, these may not be available to the network manager before purchase.

In Japan, no dedicated frequency bands have been allocated for clinical wireless communication or medical devices, so medical device manufacturers and distributors have themselves chosen their standards. Medical devices in Japan require approval by MHLW ('approval of pharmaceuticals') under the Act on the Quality, Efficacy, and Safety of Medicines and Medical Devices before they can be used in healthcare services provided by health insurance. For medical devices using wireless communication, it is necessary to obtain a technical conformity approval (so-called 'technical conformity mark') for use as a communication device from MIC before applying for pharmaceutical approval, but wireless LAN standards are not considered for review in the pharmaceutical approval process. As a result, we cannot find any technical conformity marks on the casing of some medical devices. In addition, because pharmaceutical approval takes a considerable amount of time, at least one year on average, wireless LANs with older standards are often used.

These not only affect the design of wireless LANs for business use, but also present obstacles when attempts are made to separate the bands for the wireless LANs for patients from those for business use. The presence of wireless LAN equipment based on older standards also brings the possibility that newer wireless LANs may not be able to use the higher transfer rate technologies currently available, such as "channel bonding" or "MIMO".

(2) Intensifying congestion of wireless LANs due to the introduction of VoIP for in-hospital PHS and the resulting obstacles to voice communication.

Nurse calls in Japan were in the past only connected by cable between the patient and the staff room, so nurses could not receive calls from patients when they were working outside of the staff room. Now, nurses can respond anytime, anywhere by installing and connecting to a self-owned mobile telecommunications network. When

mobile communication networks were first introduced for nurse calls, PHS, a system unique to Japan that has a low output from the terminal, was often incorporated. PHS uses radio waves in the 1.9 GHz band and has a maximum output from the terminal of only 80 mW [2,5]. PHS was also a public mobile communication network, but in January 2021 voice call services were terminated, and data services were terminated in March 2023. Although it is still available for use as a self-owned network, the price of terminals and other equipment is expected to rise in the future, so renewal to a different system has begun.

Some hospitals are using smartphones for the update. This will raise efficiency because the terminals can also be used for data communication (e.g., reference to patient information, input of vital signs, and patient identification using bar codes and RFID). When using smartphones, there are three possible communication network construction methods: using VoIP to make calls through a wireless LAN, building a new self-owned LTE network (e.g., sXGP [6]), or using a public mobile phone network. In all cases, data transfer rate is more than with PHS, but none of them is optimal in terms of cost, security, or precautions against electromagnetic interference due to the higher output compared to PHS terminals.

When using VoIP, existing hospital wireless LANs can be utilized, but the possibility of packet loss increases because the volume of information distributed suddenly increases. Packet loss in voice communication directly affects call quality. Voice communication is widely used in the medical field between patients, nurses, and doctors and, importantly, for emergency instructions. Packet loss can cause missed or misunderstood instructions, which can be life-threatening to patients. Therefore, communication networks should be constructed so that packet loss does not occur. Together with the increased use of wireless LANs for medical equipment described above, this is an issue that should be closely monitored in the future.

(3) Appropriate management of network apparatus and cables.

As mentioned above, once they are settled cables are usually not replaced for long time. However, the amount of data that flows over the cable increases with technological changes. When wireless communication systems are updated, the transfer rate over the total LAN will not increase because old cables will create a bottleneck. When replacing or installing additional cables in a working hospital, especially in wards, it is necessary, to maintain a safe and comfortable environment for patients while the renovation is ongoing, which can be difficult.

Changes in the signal range of the wireless LAN can occur when hospital renovation is done. To solve this problem, adding more APs or changing their location may be required. However, in large hospitals, the details of the renovation are often not shared with the network manager and may only be discovered after renovation is completed. Cooperation between the staff members doing the renovation and the network management staff is essential.

Many problems have been identified, and solutions need to be found for those that have occurred in the past or are likely to occur in the future. First, it is important to work with the construction company during the design phase and hospital construction to ensure that cable routes are secured. For this purpose, it is important to make the location of the terminals as clear as possible beforehand. In addition, the type of cable used should be selected based on the amount of data to be circulated and

it should be installed in such a way that it can be easily replaced when the network is updated. It is also important to control which cables connect the various sections of the hospital. Interdisciplinary cooperation is indispensable.

Next, for wireless LAN, it is important to work with the construction company during the design stage of the hospital building to ensure that radio waves (signals) reach the required location with the required strength. To achieve this, it is important to share information on the building materials, such as walls, floors, and doors, in addition to clarifying the area to be covered by the radio waves. It is also important to select the frequency band to be used for radio communication after clarifying the equipment to be used and its purpose. Electromagnetic noise sources should be identified before or at the time of installation and after the start of operation, then removed or shielded.

Furthermore, in preparing for the possibility of power outages, it is also necessary to be able to supply emergency power to network apparatus. Japanese standard JIS T 1022 [7] describes the needs for power supply to hospital facilities and medical devices, but in a modern hospital, where ICT has become more advanced with the introduction of HIS, etc., emergency power supply to information and communication equipment, including network apparatus, must be carefully considered. However, because the power circuits in telecommunications equipment can cause voltage fluctuations, the emergency power supply circuits should be separated from the ones for equipment that extract sensitive biological signals.

In addition, we believe that voice based mobile communications should use a different frequency band than those for data communications to maintain the voice quality of the call, especially in hospitals. Because several frequency bands will be used simultaneously, we believe that it will also be necessary to provide shielding technology with a selected frequency band [8]. For example, the signal reachable area for a wireless LAN band might be limited from the viewpoint of data security or eliminating interference, however, that for voice communication should not be limited. Emergency instructions must reach everywhere in the hospital.

Ultimately, we believe that dedicated frequencies should be allocated for various medical uses, especially for wireless communication by medical devices. Also, as mentioned above, to secure a stable and fast transfer rate for communication, the frequency band for voice communication should be separated from that for data communication, although a small amount of data communication could be done through the voice communication system. The relations among the purposes, systems, and frequency bands for hospital wireless communication systems are shown in **Figure 2**.

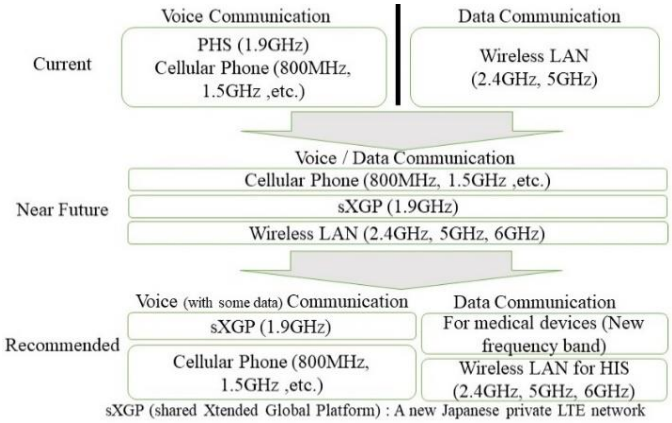

Figure 2. Wireless communication systems in hospitals [3].

5. Enhancing communication efficiency in hospital settings

Identifying current and potential challenges is of utmost importance to the seamless operation of a hospital. Accurate and rapid information sharing among medical staff is critical to protect patient safety, ensure the quality of care, and optimize overall hospital performance. The following are practical implications related to this discussion.

a) Workflow optimization:

Hospitals need streamlined processes to enhance communication. Integrating digital tools such as electronic health records (EHRs) and secure messaging systems can greatly improve the flow of information between physicians, nurses, and staff.

b) Interdisciplinary collaboration:

Effective communication fosters collaboration among diverse medical disciplines. Regular team meetings, case review sessions, and shared decision-making platforms play an important role in achieving excellent patient outcomes.

c) Reducing medical malpractice:

Clear communication, adherence to standardized protocols, and meticulous documentation are essential to reducing medical errors caused by communication breakdowns.

d) Emergency response protocols:

In an emergency situation, prompt but accurate communication can be lifesaving. Hospitals should establish protocols for promptly notifying relevant staff in the event of an emergency notification, trauma, or other emergency situation.

e) Training and education Initiatives:

Hospitals should invest in comprehensive training programs that emphasize the practical communication skills of healthcare professionals. This includes active listening, fostering empathy, and improving conflict resolution skills. By prioritizing these practical implications, hospitals can enhance their communication infrastructure and ultimately improve patient care delivery and organizational effectiveness.

6. Conclusion

In this paper we have identified current and potential problems with both cable and wireless LANs in hospitals. The quick and accurate sharing of patient information

will continue to be essential, especially when promoting team medicine. To this end, stable operation of the network is essential. Staff with information and communication technology skills are needed to identify and solve problems, such as those identified in this paper. It is our hope that each hospital will secure ICT-related departments, hospital personnel, and consultants and that they will establish management and co-operation systems appropriate to the situation so that the appropriate network can be properly implemented and operated in a safe and secure manner.

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