

Case Report

Construction of 5G all-wireless network and information system for cabin hospitals

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ABSTRACT

The epidemic of coronavirus disease 2019 (COVID-19) broke out in Wuhan, China, in early 2020. In an effort to curb the spread of the epidemic, the government has requisitioned a variety of venues and plant buildings and built more than 20 cabin hospitals to receive patients with mild symptoms within 48 hours. Under this circumstance, we worked out a 5G all-wireless solution to divide the overall network system of the cabin hospital into multiple network units by function. While ensuring good signal coverage of the local unit, each network unit was independently connected to the host hospital's data center over a virtual private network (VPN) tunnel built on the 5G wireless network. Our successful experience with the application of this 5G + VPN all-wireless network system well points to the bright prospect of 5G wireless network. In addition, the 5G + VPN solution can also be used for multihospital network interconnection and rapid network recovery during the failure of wired network.

Key words: cabin hospital, information system, 5G, all-wireless network

INTRODUCTION

The epidemic of coronavirus disease 2019 (COVID-19) broke out in Wuhan, China, in early 2020. In the early stages of outbreak, the epidemic spread quickly and sparked social panic because of insufficient knowledge of the virus, lack of protective measures, strong infectivity, long incubation period, lack of effective treatment options, and slow-improving treatment methods. Given the sudden outbreak, the local medical resources in Wuhan were insufficient to cope with the epidemic. In the face of the daunting challenge to outbreak control, General Secretary Xi Jinping held a video conference with key medical institutions in the affected areas and gave important instructions.¹ The National Health Commission of China also mobilized healthcare workers and medical supplies from all parts of China to help Wuhan contain the epidemic. The Wuhan Municipal Government decisively closed off Wuhan and announced the principle of leaving no one unattended. Given the severe fact that the number of daily confirmed cases increased by 3000 in the peak period and that the number of infected people might reach up to 100 000,

the government requisitioned a variety of venues and plant buildings and quickly built more than 20 cabin hospitals² to receive patients with mild symptoms. In the meantime, the government also transferred critically ill patients to designated medical institutions for treatment and quarantined suspected patients at hotels. Through all these efforts, the epidemic was gradually brought under control.

The construction of cabin hospitals could not be done without the support of information technology (IT). IT engineers faced a daunting challenge, as they were given 1 to 2 days to take account of the setup of network systems, the renovation of information systems, the deployment of video conference and group consultation systems, the maintenance of various types of information, and the operational management of the hospital.

DEMAND ANALYSIS AND SOLUTION DESIGN

The cabin hospital is a fast-deploying mobile medical and surgical platform combined medical resources and medical facilities.³ The

cabin hospital, which emerged in Wuhan in its most difficult time, was a new type of hospital and an important tool to prevent and control the spread of COVID-19, playing a critical role in containing the epidemic. Receiving only patients confirmed with mild and basically consistent symptoms,⁴ the cabin hospitals mainly treated patients with oral medicine and only engaged in blood testing, nucleic acid testing, mobile computed tomography (CT) scanning, and other testing functions. Inpatients were registered using their real names, and all medical expenses were borne by the government. The cabin hospitals were built by the government, which was also responsible for logistical support and supply allocation. The units were operated and managed by the local hospitals under the support of various medical teams from all parts of China. The functional units in cabin hospitals were the doctors' unit, a nurses' unit, a testing unit, an examination unit, a pharmacy, an infection control unit, a management unit, and a logistic support unit. The medical team was composed of both native and non-native medical staff from all parts of China. Not all healthcare workers came from infectious diseases departments or severe respiratory departments; thus, their working habits and approaches to treatment and diagnosis differed. Owing to the lack of experience with the operation of cabin hospitals, the entire workflow and the operational rules were determined on a temporary basis and adjusted gradually. Once the cabin hospital was put into use, the healthcare area would be immediately quarantined, and all work could only be done by individuals wearing protective clothing. Owing to the heavy workload, it was impossible to carry out large-scale construction.

The construction of IT systems for cabin hospitals typically follows a certain pattern. In order to complete the IT system construction for such a hospital within 24 to 48 hours, we usually need to include the cabin hospital within an existing hospital's information network. Specifically, we need to lease a line from an Internet service provider, connect it to the network system of the host hospital, and then route the fiber cables from the convergence switch all the way to each work unit to interconnect the computer terminals at the access layer, while wireless access points can also be deployed to provide wireless coverage. After the network is set up, the client applications of the host hospital's information system will then be installed and put into use.

However, because Wuhan was closed off, there were not many engineers and technicians available. Moreover, construction workers also had to quarantine themselves from each other. Many young people were fearful and did not want to work in or around the hospital. Vendors often provided technical support remotely, with very few being able to get to the site. The movement of people and vehicles was prohibited, equipment and supplies were snapped up, and related equipment could not be mobilized.

In the face of all these challenges, and giving consideration to such aspects as technology, management, operation and maintenance, and sustainable development,⁵ and taking account of the fact that the wireless medical healthcare management system was targeted at the frontline medical staff,⁶ we worked out a 5G all-wireless solution to divide the overall network system of the cabin hospital into multiple network units by function. While ensuring good signal coverage of the local unit, each network unit was independently connected to the host hospital's data center over a virtual private network (VPN) built on the 5G wireless network. In order to comply with relevant medical regulations, we developed this system based on the host hospital's original information system. This move reduced the difficulty and complexity in the use of traditional information systems, thereby building a cabin hospital information sys-

tem with streamlined processes, uniform access rules, and easy-to-use tools. The terminals were mainly all-in-one or laptop computers equipped with a laser printer. In this way, we could narrow the types of equipment needed and so reduce the maintenance workload.

5G ALL-WIRELESS NETWORK SYSTEM

Based on the physical location of respective functional units in the cabin hospital and the signal coverage of the wireless devices, we divided all work areas into several network units. In the cabin, we set up a registration and filing network unit at the entrance of the ward. We also set up 3 medical network units in the cabin within which patients were attended by the medical staff. Outside the cabin, we also set up a mobile CT network unit, a laboratory network unit, a pharmacy network unit, and a management network unit (8 network units in total), according to the location of each functional unit. All network units have access to the intranet and Internet. The detailed architecture and performance of the 5G all-wireless network is shown in [Figures 1 and 2](#).

5G-based wireless link

We deployed a network security gateway at the host hospital's data center to set up a VPN tunnel for accepting authenticated connections to the host hospital's information system over the Internet. Each network unit was provided with a 5G data card, and a wireless router was deployed to allow each network unit to access the Internet wirelessly. In the meantime, we connected a small branch router with VPN support to the wireless router and configured the VPN settings on this router to set up a secure, stable, and reliable authenticated link to the host hospital's data center over the Internet, thereby ensuring secure and encrypted data transmission between the cabin hospital's network units and the host hospital's data center.

Wireless network connection in the cabin hospital

The wireless router covering the local network unit was configured to access the Internet, so as to address the need for Internet access, report various types of data, and enable file sharing between the cabin hospital and the outside. The small branch router covering the local network unit was configured to access the intranet, so that the terminal computers could access the internal network and the information system of the host hospital. After testing, we found that 5G signals were stable without packet drops, that the network bandwidth was nearly 10 times faster than 4G, and that the intranet bandwidth exceeded 50M, thus meeting the demand placed on the network. Patients' need for Internet access was left to the signal coverage of telecom operators.

Cloud-based network management platform

The network administrator could use a mobile phone or desktop computer to log into the Web-based cloud network management platform to perform important tasks. They were able to set up virtual LANs. They could also configure the stateful firewalls, switches, and mobile terminals. They were able to monitor network operation status, event logs, and operation summary reports. Finally, they could optimize network parameters and configure various access control policies and network security policies such as DHCP, NAT, and QoS. This accessibility ensured the uninterrupted and secure operation of the cabin hospital's information system.⁷

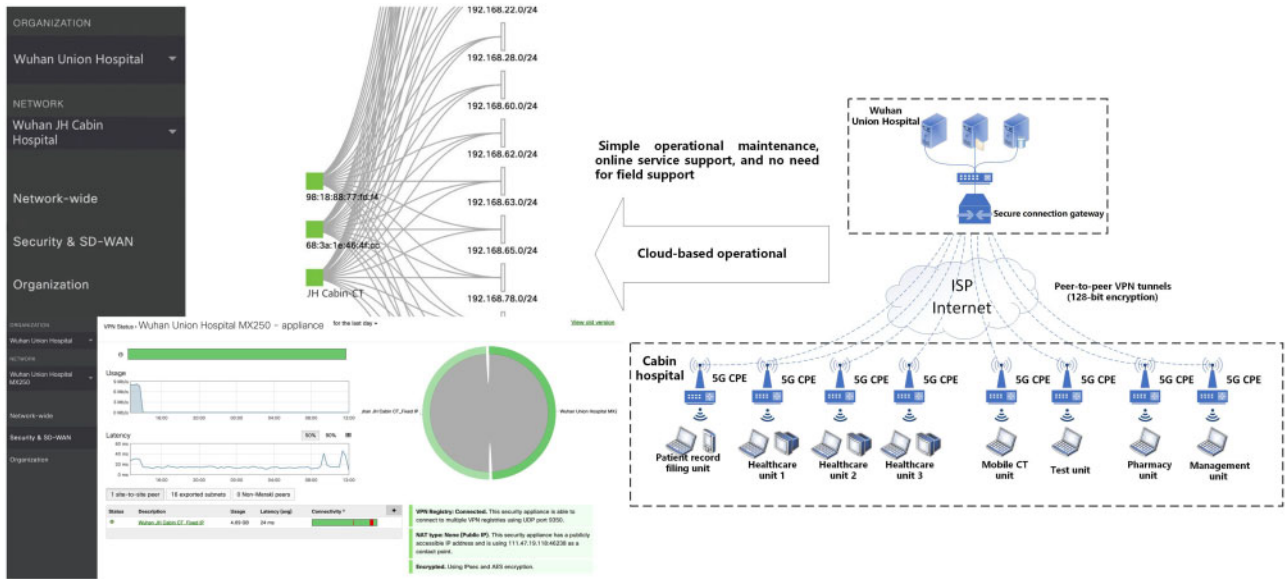


Figure 1. Architecture of the 5G all-wireless network.

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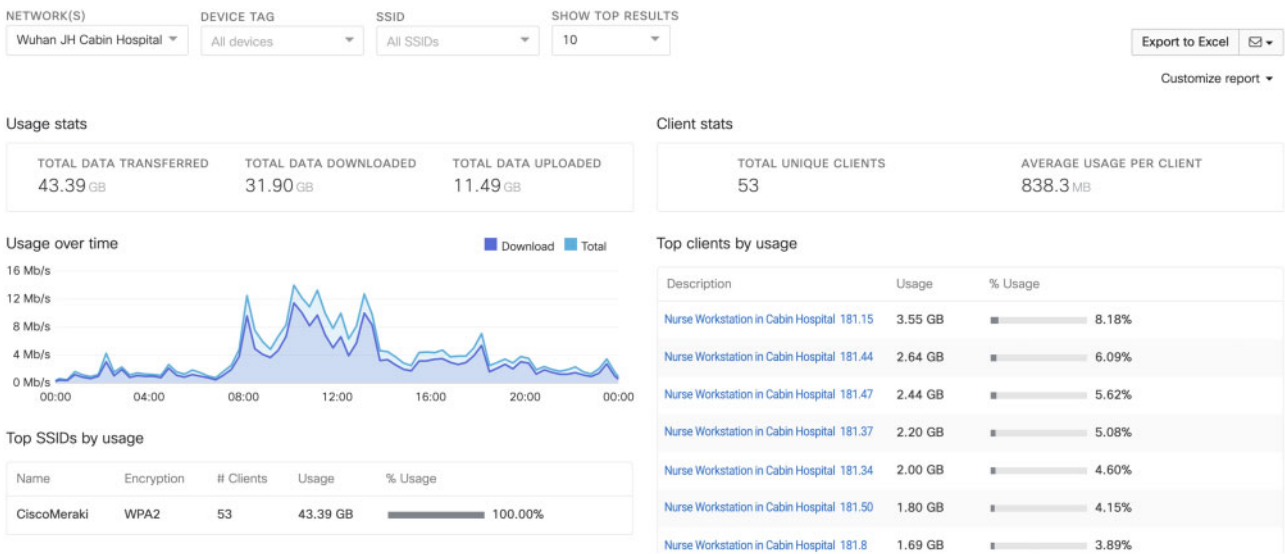


Figure 2. Network load and performance of the site's 5G network on Feb. 24th.

LIGHTWEIGHT INFORMATION SYSTEM FOR THE CABIN HOSPITAL

According to the characteristics of the cabin hospital, we developed a new information system based on the original hospital information system. By integrating the transformed electronic outpatient medical records and the picture archiving and communication system (PACS), the laboratory information system, the maintenance system, other management information systems, and the Internet-assisted medical system of the host hospital, we managed to integrate all data through the information integration platform and built a lightweight information system for the cabin hospital. The main functions of the system are shown in Table 1:

Patient record filing

The record filing was done by a nurse, who would assign a bed to each patient. All patients needed to register using their real name, as well as provide such information as hospital admission number, name, ID number, and mobile phone number. The hospital admission number consisted of 10 digits, with the first 2 digits being the cabin hospital number, the next 4 digits being the unified bed number, and the last 4 digits being the admission date (excluding the year). The hospital admission number was the unique identification number for the patient, who only needed to remember the bed number and to report the bed number to the medical staff at the time of admission. No other medium was used. Relevant information would also be sent to the patient's mobile phone.

Table 1. Main functions of the information system

No.	Main function	Description	Operator	Network type
1	Patient record filing	To create a real-name record for admitted patients	Nurse	Intranet
2	Residents' workstation	Diagnosis, medical records, medical orders, evaluation forms, etc.	Doctor	Intranet
3	Nurses' workstation	Medical order acceptance and review, care records and forms, implementation records, etc.	Nurse	Intranet
4	Radiographers' workstation	Inspection registration, implementation, image transmission, etc.	Technician	Intranet
5	Radiologists' workstation	Scan review, inspection report, audit report, report issuance, etc.	Doctor	Intranet
6	Lab technicians' workstation	Sample reception and testing, report auditing, report issuance, etc.	Technician	Intranet
7	Pharmacists' station	Medical order reception and review, medicine dispensing, statistics, etc.	Pharmacist	Intranet
8	General management workstation 1	Healthcare quality control, financial management, data collation, report generation, etc.	Administrative staff	Intranet
9	General management workstation 2	Administrative affairs, information release and transmission, official document circulation and approval, etc.	Administrative staff	Internet
10	Phone-assisted health care	Doctors used a mobile phone to check medical records and to communicate with patients	Doctor and patient	Internet

Doctors' workstation

According to the outpatient observation model, a doctor would first arrange the patient's admission, make a diagnosis, and then write the first course record. The doctor's daily routine included: filling out the electronic medical records, disease course records, and several brief evaluation forms; making a prescription for the pharmacy according to the patient's conditions and the examination and test results shown on the computer; prescribing nucleic acid tests and CT scans for the patients; and discharging or transferring the patients if their condition either improved or deteriorated. Doctors were also able to check the patient's past medical history and treatment history in real time through the quick search tool.⁸

Nurses' workstation

Nurses did not use computers much. Nurses were primarily responsible for filling out the first-time nursing evaluation form and the nursing observation record, printing the test and CT scan application summary sheets, and implementing the summary sheets. Nurses needed to print the test barcode outside the cabin, affix it to the test tube, collect the sample inside the cabin, and send it to the test unit outside the cabin. The nurses also needed to check the list in the medicine package prepared by the pharmacist for the patients and distribute the medicine. In addition, nurses also needed to perform the required checkups using the query tool and to fill out the corresponding forms based on the doctor's discharge conclusion when the patient was discharged or transferred.

Pharmacists' workstation

Patients with mild symptoms needed few medications. Because all medicines were fully supplied by the government, there was no need to set up a medicine warehouse. The main job of the pharmacist was to receive electronic prescriptions from the doctors, pack medicines separately or in batches, print the corresponding lists to be included in the medicine package, and then ask the nurses to take the medicines into the cabin. The pharmacist could stay informed of the patients' use of drugs via the summary and query tools. Pharmacists also needed to complete the in-out-stock operations independently.

Medical technology workstation

The mobile CT scanner was wired to the branch router. Upon completion of CT scanning, the patient's CT image would be transmitted to the host hospital's PACS through the wireless link of the network

unit. The radiologist at the host hospital would then use the PACS workstation to read the CT image in order to make a diagnosis and then forward the report to the doctors' station in the cabin. The test workstation would use the host hospital's laboratory information system to receive the samples, and then issue a report upon completion of the test. The mobile CT scanner could quickly and efficiently adapt to the operational pattern of the cabin hospital and could significantly enhance the capacity and outcomes of on-the-spot treatment.⁹

Online doctor assistance system

We quickly developed a doctor assistance system to support the WeChat official account and mobile application of the host hospital so that doctors could communicate with patients online in their spare time, provide consultation service for patients, answer the questions raised by patients, and if necessary, go to the bed of the patient to handle the situation. In addition, whether the doctor was in the cabin or outside the cabin, they could always view the patient information anytime via mobile phone.

OUTCOMES

Rapid and convenient system construction

With remote technical support from various vendors, engineers of the host hospital completed application development, software integration, and system integration within 48 hours. In the meantime, a brief training session was organized immediately upon arrival of the medical staff. At the time of implementation, engineers completed the installation of 50 client applications within 3 hours. After arriving at the cabin hospital, 3 engineers completed the installation of network devices and computer terminals and the power-on and printer connection tests within 6 hours. Soon, each network unit was successfully put into use.

Zero maintenance of network and terminal devices

There were only wireless routers, all-in-one computers, and several printers in the cabin. Except for the printers, there were no other cable connections. These devices were configured to support plug and play. Should any device fail or a new computer be added, the medical staff or management personnel would bring the device in and replace it by themselves. Laser printers were simple to connect and drivers could be installed remotely. Should any laser printer

encounter a paper jam or need to replace the toner cartridge, the medical staff could also do it by themselves. For the IT department, there were no on-site maintenance tasks in the cabin hospital.

Efficient and diverse means of troubleshooting

Remote maintenance software was installed on each computer. When the medical staff in the cabin encountered a problem, an engineer from the IT department could log in to the computer remotely and solve the problem quickly. For any doubts relating to the use of computers inside the cabin, the user could consult the user manual placed on each computer. They could also use a mobile phone or ultra-long-distance walkie-talkie to consult the engineer. We also created a WeChat group to answer various doubts. During our communication with users, should any reasonable demands be raised or any problems be found with the software, we would immediately arrange the development or optimization thereof and then automatically upgrade the software through remote access.

Reduced chance of cross infection

No medical card, virtual card, or bracelet was required for identification in the cabin, so there was no need to equip peripherals such as card readers or barcode scanners. Information circulation was all electronic and paper was rarely used. The nurse only needed to print the summary sheet when following doctor's order to check the patients. Still, the paper was in the hands of the nurses. All these efforts helped reduce the frequency of the medical staff's contact with the patient, reduce the chance of infection caused by the circulation of relevant medium and paper, and minimize the chance of cross-infection.

Effective saving of protective medical supplies

There were few network and information devices in the cabin. These were plug and play and basically not interconnected. The information system was maintained remotely. All system failures could be resolved online. Multiple means of communication also significantly reduced operational problems caused by insufficient training. So far, the entire network and information system has been operating stably, and engineers from the IT department have not entered the quarantine zone once. By minimizing the amount of entry into the quarantine zone, we effectively saved the protective medical supplies and indirectly contributed to the fight against the epidemic.

CONCLUSION

We creatively worked out the 5G + VPN solution and completed the deployment of an all-wireless network system for a cabin hospital within 48 hours, wirelessly connecting it to the host hospital. The deployment of a tailor-made lightweight hospital information system also enabled the online provision of auxiliary medical services. In this important fight against the epidemic, during which we must race against time to save more lives, IT engineers have made their own contributions with their IT weapons. So far, Wuhan

Jiangnan Cabin Hospital, the Cabin Hospital we are running, has been operating for more than 30 days to date. Our solution has proven to be completely feasible in practice and is worthy of replication by other cabin hospitals. During the deployment of the 5G all-wireless network (which covered installation, configuration, testing, and activation), 6 network units were set up within 1 hour. This networking mode is suitable for either indoor or outdoor applications in any emergency scenarios in which it is necessary to set up an intranet connected to the host organization within a short time. Our successful experience points to the bright prospect of 5G wireless network to dwarf the conventional wired network when communication cost is not a constraint. In addition, the solution can also be used for multihospital network interconnection and rapid network recovery during the failure of wired network.

AUTHOR CONTRIBUTIONS

BZ designed the network and information system of the cabin hospital, and drafted the article. QW designed, tested and implemented the 5G all-wireless network solution. XZ and WZ developed and tested the information system of the cabin hospital. WW tested and implemented the 5G all-wireless network system. ZG contributed the conceptual design, network architecture diagram, and functional table of the information system.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. CNR Military Channel. Huoshenshan Hospital earnestly studying and implementing the spirit of President Xi Jinping's important speech and sparing no effort in treating patients [EB/OL]. http://military.cnr.cn/ydcj/20200211/t20200211_524970513.html Accessed February 23, 2020.
2. Wang YT. *Chinese Disaster Rescuing Medical Science*. Beijing, China: Peking Union Medical College; 2017.
3. Hubei D. A visit to 13 cabin hospitals: life shelters are being put into use one by one [EB/OL]. http://military.cnr.cn/ydcj/20200211/t20200211_524970513.html Accessed February 23, 2020.
4. Changjiang Daily. Wuhan built cabin hospitals overnight to receive patients with mild symptoms. http://cjrj.cjn.cn/html/2020-02/04/node_1.htm Accessed February 23, 2020.
5. Tang B, Huang Y. Security optimization schemes for hospital information system under grade 3 protection. *China Med Device* 2018; (9): 136–40.
6. Liu Y. Digital wireless healthcare management system for improving hospital management. *Chin J Hosp Admin* 2009; 25 (12): 856–8.
7. Lu C, Haoyu Z, Jingbo L. Solutions and measures for the secure management of hospital network. *Chin Hosp Manage* 2017; 37 (2): 56–7.
8. Zhou B, Minfang C, Wei Z, et al. Continuous improvement of outpatient digital medical services in large hospitals. *Chin Hosp Manage* 2019; 39 (6): 46–7.
9. Wu C, Shulin T, Weihua S, et al. Design of on-vehicle mobile CT cabin. *Chin Med Equip J* 2013; 34 (6): 7–10.