5G Technologies Based Remote E-Health: Architecture, Applications, and Solutions

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Abstract

Currently, many countries are facing the problems of aging population, serious imbalance of medical resources supply and demand, as well as uneven geographical distribution, resulting in a huge demand for remote e-health. Particularly, with invasions of COVID-19, the health of people and even social stability have been challenged unprecedentedly. To contribute to these urgent problems, this article proposes a general architecture of the remote e-health, where the city hospital provides the technical supports and services for remote hospitals. Meanwhile, 5G technologies supported telemedicine is introduced to satisfy the high-speed transmission of massive multimedia medical data, and further realize the sharing of medical resources. Moreover, to turn passivity into initiative to prevent COVID-19, a broad area epidemic prevention and control scheme is also investigated, especially for the remote areas. We discuss their principles and key features, and foresee the challenges, opportunities, and future research trends. Finally, a node value and content popularity based caching strategy is introduced to provide a preliminary solution of the massive data storage and low-latency transmission.
I. INTRODUCTION

With the extreme unbalanced distribution of medical resources, there is a big gap between the developed areas and economically backward areas in terms of the equipment, technology service quality of medical, resulting in rapid demands for telemedicine [1]. The original intention of telemedicine is to improve the popularity of medical and health services via telecommunication for medics [2]. With the strong support of market policy and progress of wireless technology, telemedicine has been developed significantly [3]. Currently, relying on the advanced communication and computer technologies to transmit the data, voice, image, video and other information, telemedicine can realize the treatment, diagnosis, health care and consultation in real-time for the remote patients, as well as provide the education and training for remote medics, which breaks the space and time limitations [3], [4]. Moreover, the telemedicine not only changes the medical experience for patients, but also improves the medic-patient relationship. When the patients seek medical treatment, the medic will take their emotions into account to strive for positive treatment evaluations. It is easy to see that, telemedicine will break the barriers among different industries, optimize the medical service process, improve the overall service efficiency, and constantly resolve the problems provided by complicated medical procedures.

As the core support of telemedicine, with decades of development and continuous consumption upgrading, the wireless communication technology has completed the evolutions from 1G to 5G [5]–[7]. It realizes the high-quality transmission of three dimensional images to provide high-quality video servicesdata acquisition, positioning, remote diagnosis and treatment and other fusion functions in real-time. Compared with other generations of wireless communications, 5G has advantages in terms of the low latency, high reliability and mobility, providing great opportunity for the development of telemedicine [3]. On the basis of traditional medicine, 5G technologies based telemedicine integrates mobile communication, Internet, Internet of things (IoT) [7], cloud computing, big data, artificial intelligence (AI) [9] and other advanced information and communication technologies, applying to the remote surgery, remote consultation, remote health monitoring and emergency command. In particular, telemedicine will provide more choices and ways for rescue, especially in the fast moving state of vehicle and harsh environment.

It worth noting that, since that the 5G technology, business model and industrial ecology are still evolving and exploring, the architecture, system design and landing mode of telemedicine are not completed. These arise the following problems problems: The imperfect overall planning,
and the problem of cross departmental coordination; lack of technical verification and feasibility study; inconsistent medical standards; privacy security [6], [10]. On the other hand, with the spread of COVID-19 [11], [12], physical and mental health of people has been greatly impacted, leading to that the concern of people has gradually transferred from the disease treatment to disease prevention and health management. Moreover, in order to realize remote sharing of medical resources, the massive data storage and data redundancy will bring great load to the server. With these observations, the goal of this article is to provide a potential solution to realize 5G technologies-based remote e-health, spanning from the general architecture and framework of telemedicine, to satisfy the high-speed transmission of massive multimedia medical data and realize the sharing of medical resources. In order to track and control the spread of the COVID-19, the broad area epidemic prevention and control (BAEPC) design for COVID-19 is proposed, as well as the node value and content popularity (NVCP) based caching strategy is investigated to overcome the massive data storage and low-latency transmission issues.

The rest of this article is organized as follows. First, we provide a general architecture of the remote e-health. Then the 5G technologies based telemedicine framework is introduced for the remote hospital. Moreover, a broad area epidemic prevention and control scheme is investigated to prevent COVID-19, as well as the node value and content popularity based caching strategy is studied. Finally, we draw the main conclusions and interesting future research.

II. THE PROPOSED REMOTE E-HEALTH ARCHITECTURE

Relying on computer technology and remote sensing, telemetry, remote control technologies, telemedicine gives play to advantages of medical technologies and equipments in city hospital to conduct remote diagnosis, treatment and consultation for patients in remote areas i.e., remote imaging, remote nursing and other medical activities. The proposed remote e-health architecture based on cloud network is shown in Fig. 1, which consists of the city hospital and many corresponding remote hospitals. The concepts of the proposed architecture is that, with the internet as link, grading diagnosis and treatment as the core and the substance hospital as the support, the remote hospitals and advanced city hospitals will be connected to this platform. By this way, the remote hospitals can also enjoy the remote outpatient service, expert appointment, electronic prescription, online payment and other fast services through the internet. As the brain, the city hospital provides the technical supports and services for these remote hospitals, in the meanwhile that the remote hospitals share information and data for each other according to the
Fig. 1. Illustration of the remote e-health architecture.

networks, to improve the utilization of medical resources. For the city hospital, the details of the processing strategies can be summarized as follows:

- When a request for medical help from a remote hospital is received, according to the received contents, i.e., the images, voices and videos for the patients, the city hospital rapidly makes decisions and corresponding measures to cooperatively help remote hospital curing the patients, through the existing advanced technologies and equipments.
- For the difficult miscellaneous diseases, the city hospital convenes experts and relevant medics to hold the consultation. Moreover, for very special and difficult cases, the remote consultation with other advanced city hospitals will be adopted. When the specific treatment plan is formulated, the city hospital will promptly contact and assist the remote hospital to take corresponding measures. In the meanwhile, the electronic medical record is established.
- According to the progress of conditions of the patients, the electronic medical record will be updated in real-time, until the patient is fully recovered. The electronic medical records
are also shared with the remote hospitals for follow-up actions and future study. Moreover, for emergencies, the city hospital will dispatch the intelligent ambulance and medics to the remote hospitals.

All the city and remote hospitals will share and update the information through the cloud network. Clearly, the use of telemedicine not only significantly reduce the time and cost of the diagnosis and treatment, but also can well manage and distribute emergency medical services in remote areas. Specifically, it can make medics break through the limitation of geographical scope and share the case and diagnosis photos of patients, which is conducive to the development of clinical research. In addition, it can provide a better medical education for medics in remote areas.

Since that the telemedicine technology is in its development stage, the design of its architecture and corresponding strategies are different from the traditional medical system. The key issues and challenges for telemedicine are generally summarized as follows:

- **Privacy security**: Any breakthrough in science and technology has to face the problem of security, the telemedicine technology is no exception. If the medics or medical equipments do not consider the security of electronic data of patients, once these data are transmitted and leaked through the Internet, it will cause irreparable security risks. Therefore, it is necessary that, adopting 5G technology and network security methods to authenticate, encrypt and protect the intelligent medical equipment for privacy preservations. Only by taking precautions in advance, remote medical can realize the transformation from the passive defense to active response.

- **Medical data and resource sharing**: Medical data and resource sharing can not only help the rapid development of the telemedicine technology, but also significantly alleviate the shortage of medics. However, when telemedicine is performed, it has to connect to Internet, and in this docking process, the systems of hospitals are relatively closed; the electronic systems of different hospitals are built by different enterprises; and there exists barriers between these systems among enterprises, resulting in a difficult integration for the data from different hospitals. Therefore, how to reasonably and legally realize the sharing of massive medical data to the Internet is still an open problem and challenge.

- **Massive connectivity and data cache**: With the commercial application of 5G, the real-time data transmission problem for telemedicine technology has been solved in some degree, eliminating the barriers and distance for medical communication. However, the massive
connectivity from the medical devices, intelligent devices and remote hospitals, as well as the cache of the massive medical data challenges the existing spectrum resources and network structure. Therefore, it is necessary to adopt the technologies with the excellent spectrum efficiency and effective cache capacity.

III. 5G TECHNOLOGIES BASED TELEMEDICINE FRAMEWORK

On the basis of traditional medicine, 5G technologies based telemedicine integrates wireless communication technology of smart equipment and high-speed mobile communication technology in various modes, which can realize the operation of remote surgery, remote consultation, patient monitoring, command and decision-making for emergency rescue events. Moreover, 5G-based telemedicine can also support the high-speed transmission of massive multimedia medical data, and further realize the sharing of medical resources. With this prospect, as shown in Fig. 2, the remote hospital is readily allowed the patients, local medics, schools, factories, personal devices and local intelligent ambulances access to its server to apply the medical resources and share the medical data.
Nowadays, medical service has changed from the disease treatment to health care, meanwhile, the disease prevention and health management are becoming increasingly important. With the wearable medical devices and mobile private doctor, people can know their personal physical signs, i.e., blood pressure, heart rate and temperature, at any time and any where to enjoy high quality health services and e-health education. In addition, through the monitoring of these devices, medical institutions and medics can take the initiative to find individuals and groups with abnormal health status, and give health risk tips, health improvement or medical measures suggestions in advance. In this manner, the hospitals can improve diagnosis efficiency, and residents can reduce the cost of health consultation. In addition, based on internet of medical things (IoMT) and AI, for any emergency, the patients can be timely and tentatively cured in the ambulance to realize the vision of “In ambulance, in hospital”. According to the 5G HD video feedback from the ambulance, the hospital can conduct real-time follow up and analyze the signs and conditions of patients in advance, to effectively reduce the risk of death. On the other hand, with the development of 5G-based global positioning system (5G-GPS), it can provide more accurate positioning, more intelligent navigation and more information services in real time for the patients and ambulance, especially for remote areas. Predictably, telemedicine can improve the medical experience of the patients, and constantly resolve the problems of “complicated treatment process”. Moreover, it also provides more possibilities to make up for the insufficient and unbalanced distribution of medical resources and solve the problem of social aging.

IV. BROAD AREA EPIDEMIC PREVENTION AND CONTROL FOR COVID-19

With invasions of COVID-19, due to the continuous person-to-person transmission, the coronavirus rapidly spreads leading to cross infection for many patients. Since that there is no effective cure method and vaccine, and it is hard to detect millions of people on a large scale, the strict segregation and control measures have to be adopted. Unavoidably, the economic development and quality of life of the people have been greatly impacted, even resulting in a social panic. Without radical cure, effective and rapid detection to prevent the spread of the coronavirus has become the primary task. Currently, the common detection method is that, at the entrance and exit with large flow of people, the thermal cameras or temperature guns are used to locally detect the temperature of people in turn. Clearly, such detections have the following defects:

- **Omissions in personnel inspection**: The tested personnel are passively restricted, not all of them will be detected. For example, some people do not take the initiative or cooperate
with the measurement, especially that the people in remote areas have weak awareness of protection;

- **Real-time issue:** This kind of epidemic prevention and control is not real-time due to the rapidly spreading of coronavirus. It is inevitable to cross infection in the detection process, especially in remote areas;

- **Locality issue:** Due to that COVID-19 is a global problem, it is difficult to make personnel information open and personnel information transparent among different regions, which makes it necessary to provide a lot of manpower and material resources when people flow between regions;

- **Security issue:** On one hand, patient information is presented by the text registration; on the other hand, most of the body temperature and pathological features are shown in the form of pictures. It is easy to see that this intuitive way will inevitably be used by eavesdroppers providing troubles to patients.

In order to turn passivity into initiative, a BAEPC for COVID-19 is proposed as shown in Fig. 3. With the development of the high-definition cameras and video surveillance, currently, ultra long
distance thermal camera (ULDTC) can monitor a circumference of 15 Km. The basic idea of this scheme is that distribute these rotatable ULDTC in different areas for independent monitoring, and centralize the collected information to the control center (remote hospital) via the 5G-network for centralized processing. In addition, the people should carry wearable medical devices, by this way, the trajectories of people will be collected by the remote hospital to determine coordinates of people during their outdoor activities. In this manner, the people can receive personal information and surrounding conditions from the remote hospital at any time, to avoid cross infection when abnormal body temperature occurs. Accordingly, when people themselves or close contacts have abnormal body temperature, they will receive warning messages in time and make self isolation until temperature normal or 14 days. Due to huge amount of data, it is considered that the people staying at home or in their vehicles are isolated, the remote hospital will not collect their coordinates until they go out for activities or take the initiative to contact remote hospital. When the fever have stayed high, after receiving the request for help, the patient will be sent to the remote hospital for a further observation and treatment by the ambulance.

V. NODE VALUE AND CONTENT POPULARITY BASED CACHING STRATEGY

Even that, the proposed BAEPC scheme can effectively and promptly confine and eliminate the coronavirus, however, the massive data storage and data redundancy will bring great load to the server. Moreover, due to that the key of telemedicine technology lies in long-distance and low-latency connections, TCP/IP networking approach is hard to satisfy these requirements. In this section, a NVCP based caching strategy for content-centric networking (CCN) will be introduced to provide a preliminary solution. In what following, after defining the cache content, the proposed NVCP caching strategy will be discussed within two algorithms.

A. Cache locality

In this subsection, three node attributes are defined to evaluate the value of node, which are based on the graph theory and described. Moreover, we further considered that the Named-data Link State Routing Protocol (NLSR) is adopted to query the shortest path information. Given an undirected graph $G = (V, E)$ with $n$ vertexes and $m$ edges, where $V = \{v_1, v_2, ..., v_n\}$ represents a set of content routers, and $E = \{e_1, e_2, ..., e_m\}$ denotes the links between the content routers. Moreover, $A = (a_{ij})_{n \times n}$ is the adjacency matrix of $G$, for $v_i$ directly connect with $v_j$ and $a_{ij} = 1$, otherwise $a_{ij} = 0$. 
1) **Connectivity**: Different forwarding strategies result in different routing paths for the requested content, cache nodes will play different roles in these strategies. And hence, we regard the number of paths that the requested content pass through the cache node as the connectivity of the node. Therefore, with the increasing paths, the request content becomes more important. Defining the number of routing paths, which is requested content \( k \) passes through \( v_i \), as \( c_s(v_i) \), and the maximum number of routing paths passing through \( v_i \) as \( c_s^{max}(v_i) \), the connectivity can be obtained as the ratio of \( c_s(v_i) \) to \( c_s(v_i)^{max} \) defended as \( C_s(v_i) \).

2) **Betweenness centrality**: If a content router is on the shortest paths between the corresponding content routers, the content router is considered to be in a significant position. It is reasonable, due to that the content router in this position can affect the overall network by controlling or misinterpreting the transmission of information. The ability to characterize content router control information transfer is betweenness centrality (also known as node median) [13]. Defending \( \sigma_{st} \) as the number of shortest paths between \( v_s \) and \( v_t \), \( \sigma_{st}(v_i) \) as the number of shortest paths from \( v_s \) to \( v_t \) through \( v_i \), the betweenness centrality of \( v_i \) can be presented as

\[
C_B(v_i) = \left( \frac{(n - 1)(n - 2)}{2} \right)^{-1} \sum_{s \neq t \neq i \in v} \frac{\sigma_{st}(v_i)}{\sigma_{st}},
\]

where \( n \) represents the number of content routers.

3) **Eigenvector centrality**: In fact, the influence of a content router is not only related to its own locality, but also to the influence of its neighbors [14]. If the content router is chosen by a very popular actor, the corresponding influence will also be increased. On the other hand, there is an influence on an influential node, it is clear that the influence will be even greater, where the eigenvector centrality is used to characterize the influence. We define \( C_E(v_i) \) as the eigenvector centrality of a node, indicating the influence of the neighbors of nodes. It is also defended that \( C_E(v_i) \) not only reflects the relative centrality of the network, but also reflects the long-term influence of the node.

The connectivity and betweenness centrality consider the value of nodes from routing paths of the requested contents, meanwhile that the eigenvector centrality takes the influence of neighbors into account. When select the cache locality, the NVCP considers the above three attributes
simultaneously. Defining $M(v_i)$ as the comprehensive attribute, we have:

$$M(v_i) = \alpha C_S(v_i) + \beta C_B(v_i) + \gamma C_E(v_i),$$

where $\alpha, \beta, \gamma$ represent the weight of connectivity, betweenness centrality and eigenvector centrality, and the sum of them is 1. It is worth noting that, in our proposed scheme, three mentioned attributes have difference influences on the chosen of the cache locality. Based on which, when different attributes are used to evaluate the importance of nodes in a same network, the corresponding different results will be obtained. Therefore, the coefficients in the comprehensive attribute $M(v_i)$ are determined by the related requirements of CCN.

**B. Cache content**

Since that whether caching every content which pass through the content router is another problem for the CCN, the popularity is a factor to draw the content. The popularity of content can be estimated by the content request count during a measurement, which means that the more content request counts, the greater the popularity and probability of the content will be requested. Assuming that the count requesting for the content $k$ at $v_i$ is $f_{v_i,k}$, and the max count of $v_i$ is $f_{v_i}^{max}$, finally, we have the popularity of content $k$ can be presented as $P_{v_i}(k) = \frac{f_{v_i,k}}{f_{v_i}^{max}}$.

**C. The NVCP cache strategy**

For the proposed NVCP, the core idea is based on the node value and content popularity, a table is considered to be added at each content node including the content name, the number of routing path and count of content request to store the information of content and cache node. It is remarkable that, in CCN/NDN, PIT records the requests that have not been satisfied, including the content name and corresponding arrival interface, to ensure the returned response packet to the content requester along the reverse path. Therefore, the source of a request is identified through PIT. By this way, when a consumer requests a content, the betweenness centrality and eigenvector centrality of the nodes on the delivery path will be calculated and normalized. Once the request is satisfied, the data packet is returned on the inverse delivery path. At this time, the content popularity will be calculated according to the count of content request. In our proposed scheme, we design a variable $\varphi$ to match the content popularity and node value given as $\varphi = \frac{P_{v_i,k}}{M(v_i)}$, where $P_{v_i}(k)$ is the popularity of content $k$ at $v_i$, and the values of $P_{v_i,k}$ and $M(v_i)$ are fixed and less than 1. In general, there are two cases: (1) $P_{v_i,k} \geq M(v_i)$, it means
TABLE I
OBTAIN THE BETWEENNESS CENTRALITY AND EIGENVECTOR CENTRALITY

Algorithm 1: Set the forward path

G: The network topology
Initialize $c_S(v_i), C_B(v_i), C_E(v_i), f_{v_i,k}$
for node on the delivery path from consumer to sever do
  if content in cache
    then send content back to the consumer
discard interest packet
  else
    get the adjacency matrix of the nodes according G
    $\sigma_{st}$: record the number of shortest paths between $v_s$ and $v_t$
    $\sigma_{st}(v_i)$: record number of shortest paths from $v_s$ to $v_t$ through $v_i$
calculate $C_B(v_i), C_E(v_i)$
    $c_S(v_i) \leftarrow c_S(v_i) + 1$
    $f_{v_i,k} \leftarrow f_{v_i,k} + 1$
    forward the interest packet to the next hop towards server
  end if
end for

that the popularity of content is more important than the value of node. Therefore, caching the content in the content router can obtain a higher cache hit rate. (2) $P_{v_i,k} < M(v_i)$, it means that the value of the node is high, but the corresponding popularity of the content is low. If caching content with a lower popularity will result in a waste of the cache space.

The main idea of the proposed NVCP is presented in Algorithms 1 and 2. In our proposed scheme, considering that the location of content router does not change, we have a fixed network topology. Therefore, the network can be seen as an undirected graph, the corresponding algorithms (such as Brande algorithm and Power Iteration) will be used to obtain $C_B(v_i)$ and $C_E(v_i)$ in advance, resulting in a computational complexity as $O(VE)$ for these two algorithm. Algorithm 1 is the process to obtain the betweenness centrality and eigenvector centrality. It is clear that, when the interest packet arrives at a content router, if the CS has the content, sends the content back to the consumer, otherwise calculates $C_B(v_i)$ and $C_E(v_i)$ according to the network topology. In the meanwhile, the values of $C_S(v_i)$ and $f_{v_i,k}$ increase by 1. On the other hand, algorithm 2 illustrates the process to select the appropriate cache locality and cache
Algorithm 2: Select cache locality and cache content

G: The network topology
Input $c_S(v_i), C_B(v_i), C_E(v_i), f(v_i, k)$

for node on the delivery path from server to consumer do
  if the content is provided by server
    then send the data packet back directly
  else
    calculate $C_S(v_i), P(v_i, k)$
    get $C_B(v_i), C_E(v_i)$
    $M_{v_i} \leftarrow \alpha C_S(v_i) + \beta C_B(v_i) + \gamma C_E(v_i)$
  end if
  if $\varphi = \frac{P(v_i, k)}{M(v_i)} \geq 1$
    then cache the contents
  else
    forward the data packet to the next hop to the consumer
  end if
end for

content. According to the results given in Algorithm 1, calculate $\varphi$. If $\varphi > 1$, cache the content, otherwise forward the data packet to the next hop. In addition, considering the fixed locations of content routers, the values of $C_B(V_i)$ and $C_E(V_i)$ only need to be calculated once. By this way, when be requested, the popularity of content increases by 1, which is easy to realize. Clearly, compared with the existing works, our proposed algorithm significantly improve the efficiency for calculating the value of $\varphi$. Clearly, the computational complexities of Algorithms 1 and 2 are not extremely high, which are practical and acceptable.

D. Simulation Results

The simulation uses a network topology generated randomly, which consists of 50 nodes and 150 links. There is a source server in the network, which is connected to a node randomly, and the edge nodes are connected to the consumers. Content requests are generated following the Zipf-Mandelbrot distribution with $a = 0.7$. The total number of different contents will be requested in the network as 10,000. Further assume that the interests of each consumer are generated following the Poisson distribution with $\lambda = 100/s$. Comprehensive consideration of the various attributes of the node, for simplicity and fairness, in this article, the specific weight
Fig. 4. The impact of cache size on the system performance for the proposed and existing caching schemes versus the cache size.

values of $\alpha$ (connectivity), $\beta$ (betweenness centrality), and $\gamma$ (eigenvector centrality) in the presented simulation results are equivalently given as $1/3$. The Least Recently Used (LRU) [15] is employed as the cache replacement strategy and the total simulation time is 100s. More specially, the simulations results have been evaluated for various values of the cache size. The main simulation parameters are listed in Table III.

| Parameter     | Default value | Variation range |
|---------------|---------------|-----------------|
| Nodes         | 50            | -               |
| Links         | 150           | -               |
| Delay/ms      | 10            | -               |
| Bandwidth/Mbps| 10            | -               |
| Contents      | 10,000        | -               |
| Consumers     | 18            | -               |
| Cache size    | 1,000         | 100 $\sim$ 2,000 |
| zipf($a$)     | 0.7           | 0.1 $\sim$ 1.0  |
| Simulation time/s | 100    | -               |

The proposed NVCP strategy is compared with the LCE, Prob(0.5) and MPC in terms of the cache hit ratio, average hop count and average transmission latency as show in Fig. 4. It is easy to see that the cache hit ratios of the four cache strategies are gradually increased, and the cache hit ratio of the NVCP is significantly better than the others. It is resealable, because the LCE requires all nodes on the delivery path cache contents without difference, which results in a large amount of content redundancy and replace frequently. In addition, the Prob(0.5) caches contents passing through the cache nodes with a fixed probability. Even taht the
cache space is reduced, it still causes the content redundancy and low content diversity. Instead of storing all the content at each node on the path, MPC caches only the popular contents. On the contrary, the NVCP considers node value and content popularity comprehensively, where the content with higher popularity is cached in nodes with higher value, in the meanwhile that the content with lower popularity is cached in nodes with lower value, which significantly reduces the replacement frequency, improves the content diversity, and reduces the content redundancy. Compared to the LCE, Prob(0.5) and MPC schemes, the proposed NVCP cache hit rate has a 11% to 15% improvement. The second and third subfigures show that as the cache capacity of the node increases, the average hop count and the average transmission delay decrease gradually. Moreover, the performance of NVCP is better than the other schemes. This is due to that the LCE caches content indiscriminately, Prob(0.5) takes the probability caching, and the MPC only caches the most popular content without any requirements for the nodes. On the contrary, the NVCP comprehensively evaluates node value from the connectivity, betweenness centrality and eigenvector centrality, assigns different weights according to different requirements, which improves the response speed to the content request, as well as, reduce the network overhead. Compared with the traditional cache strategies, the proposed NVCP has a great improvement of the average hop count and average transmission latency. Compared with LCE, prob(0.5) and MPC, the average hop count of NVCP is reduced by 0.08 \sim 0.17 hops and the average transmission latency is reduced by 8 \sim 15ms.

VI. CONCLUDING REMARKS

By seamlessly converging 5G technologies and telemedicine to realize the remote surgery, remote consultation and patient monitoring, people in remote areas can receive high quality services from developed areas, improving the utilization efficiency of medical resources and reducing the time and cost of the diagnosis. In this article, we first characterized the general architecture of the remote e-health, and then introduced 5G technologies supported telemedicine to satisfy the high-speed transmission of massive multimedia medical data, and further realize the sharing of medical resources. In addition, the BAEPC scheme was proposed to track and control the spread of the COVID-19. The challenges, opportunities, and future research trends, as well as the open issues for the remote e-health are provided. Finally, the NVCP based caching strategy was investigated to overcome the massive data storage and low-latency transmission issues. The interesting future research avenues would be that introduce the “Big Data + AI”
into telemedicine, to construct the application of AI assisted diagnosis and treatment; modeling and analyzing the imaging medical data to provide decision support for medics and improve the medical efficiency and quality; with the blockchain technology, encrypt the underlying data to realize the secure and reliable transmission of medical privacy data.

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