VIRTUAL VISITS TO ICU

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Abstract: 21st Century world requires transparency in all the operations and procedures, may it be government or any private sector organizations. Hospitals and health care systems require transparency in the way they work and operate. For example, monitoring what happens inside an ICU or Operation theater requires transparency because of incidents of clinical trials, drug abuse and smuggling of organs reported. In case of a quarantined patient, his/her visitors are prone to be infected and also if the visitors carry foreign bodies, it might affect other patients in the ICU. The system presented here in the paper tries to solve the above problems by providing a simple and cost-effective solution.

IndexTerms - ReactJS, HLS, API, OTP, Streaming Services

I. INTRODUCTION

As much as hospitals are places of hope, of second chances and recovery, they can also be the cause of severe anxiety and financial burden for many. When a loved one is seriously ill or injured, we tend to completely trust a hospital and its doctors, without so much as a shadow of a doubt. Now, we are not saying that someone can take advantage of this situation, but it is crucial for everyone to know about their rights at every place. Keeping this in mind, the Ministry of Health and Family Welfare (MoHFW) released a ‘Charter of Patients Rights’ [0] that compiles the lawful rights as stated in the Constitution of India. Some of the rights include right to information, right to reports and records, right to informed consent and right to confidentiality, human dignity and privacy.

Admission to the Intensive Care Unit (ICU) is a crisis situation for the patient and his family members. Being in an unfamiliar environment, fear, feeling hopelessness and lack of awareness about the disease are among factors that can cause a crisis in these patients and their family members [1]. Paying attention to the specific needs of these patients and their families, and responsiveness of nurses and doctors in these unites are one of the essential elements of quality of care [2]. Visiting patient as a positive and effective way to help patients and families to adapt better with stress and crisis has been highlighted in many studies [3-5]. The importance of these issues is to such an extent that health policy makers in some countries have offered medical centres the implementation of open and flexible visitation [6]. On the other hand, the physical space restrictions and other obstacles ahead have created much discussion about the management of visiting hour’s policies in ICUs [7]. Thus, there is no consensus on a particular model for this issue [8].

Visiting a patient in an ICU also risks the spreading of infection by foreign bodies being carried by visitors into the ICU or vice-versa.

Factors that may affect the transfer of microorganisms from one surface to another and cross-contamination rates are type of organisms, source and destination surfaces, humidity level, and size of inoculum [15, 16]. However, other factors playing a role in contamination and cross-transmission rate in the ICU may include hand hygiene compliance, nurse-staffing levels, frequency/number of colonized or infected patients, ICU structural features (e.g., single-bed or multi-bed ICU rooms) and adoption of antibiotic stewardship programs [17, 18]. The issue of environmental contamination may pose an even greater challenge in the ICU, where patients are critically ill, with several risk factors for nosocomial infections [19], and the highest standard measures for infection prevention cannot always be addressed due to impelling, life-threatening conditions.

II. PROBLEM

A growing body of evidence supports the contribution of inanimate surface and equipment contamination for transmission of pathogens to ICU patients. Healthcare workers' hands and the visitors' hands are the major vector of cross-transmission of pathogens, with an estimated 20 to 40 % of nosocomial infections arising from cross-infections via healthcare personnel hands [11, 23]. Bacterial contamination of caregivers' hands increases linearly over time, with a progressively higher grade of contamination with longer duration of care [24]. It commonly occurs after direct patient contact. However, healthcare workers or visitors may contaminate their hands after contact with inanimate surfaces surrounding a patient's bed (e.g., ground, bedrails, emergency carts, and trolleys) or after usage of high-contact equipment items and objects (e.g., stethoscopes, monitors, ventilators, phones, medical charts) [9, 25, 26]. Evidence from observational studies identifies colonized and infected patients as a reservoir for environmental contamination [16, 27]. Frequently touched surfaces and objects in the immediate vicinity of patients are more frequently and heavily contaminated [9]. The concepts of *patient zone* and *healthcare area* have been proposed as a user-centered, geographically related model designed to improve hand hygiene compliance by healthcare personnel during their daily workflow. The patient zone encompasses the patient and his/her immediate surroundings. Inanimate surfaces in the patient zone are rapidly contaminated by microorganisms after direct patient shedding of bacteria, or indirectly due to high-frequency interactions between visitors' hands and high-touch surfaces (e.g., monitors, ventilator buttons, bedrails), in the patient zone. The healthcare area includes all surfaces outside a given patient zone, namely the healthcare facility environment and other patient zones. Healthcare area may be contaminated by microorganisms from different patient zones [28].

III. SOLUTION

System Design: The main goal of the system is to provide a reliable and efficient means of communication between hospital and the parties associated with the patients. Some design goals are as follows:

- To be fast, efficient and reliable.
- The system must be secure and should protect the privacy of data.
- The system must try to make use of existing resources, i.e. the expenditure involved in implementation must be minimal.

The primary focus of the application is to be portable, for this reason we selected web as the platform, latest advancements in client side technologies has enabled rich user experience on browsers, moreover by selecting web as the platform , we do not force the users to possess expensive devices or install any application explicitly. The application is modular in nature and uses REST (Representational State Transfer) as a primary protocol for communication.

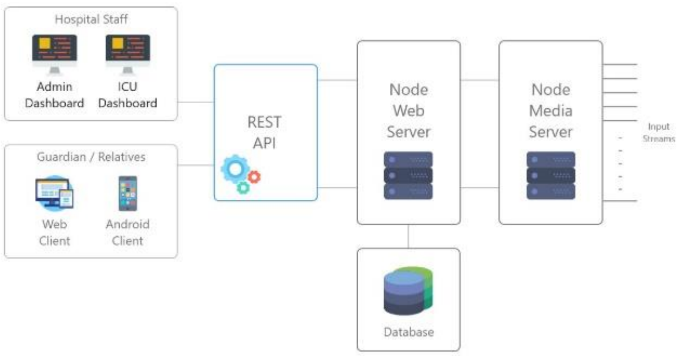

Fig 1. Application Architecture

The system uses Mongo DB as the primary database, we selected Mongo DB because it is unstructured and scalable, since it is a No-SQL database, it is easy to store records and retrieve them just like a document in the file system. Node web server is the centralized control unit of the entire system, it implements and exposes REST APIs for the database. The primary focus of the application development is to ensure heterogeneity, REST APIs are the best candidates for heterogeneity because they make use of HTTP as the underlying communication protocol, since HTTP is a standard of the web, any device that has TCP/IP can use REST protocol. The server is built using Node.js, using express.js as the framework, when compared to alternatives, express.js provides best performance because of optimized event loop and multi-threading. Node web server manages client connections as well as provides interface for video streaming.

Node Media Server (NMS) is a dedicated video streaming server that provides live video streaming. There are two types of communications we are focusing on, one way communication and two-way conference system. The one way communication is developed using FFMPEG and HLS (HTTP live streaming). FFMPEG is a C / C++ native library supporting encoding and decoding of various video formats, FFMPEG can also be adjusted for parallelism to improve performance. HLS is a streaming protocol, it has two advantages, it is used for high bandwidth transmission of data and it is portable since it used HTTP for transmission and can be easily consumed by client video players. Unlike one way communication, the two way conference technology requires even more bandwidth and decentralization, in order to support the requirements we selected WebRTC as the media protocol. The major advantage of using WebRTC is decentralization. In one way communication system, the frames were processed by server, if the server handled 30 connections at a given time, then there would be 30 processing threads in the server, when it comes to two-way communication the threads required would be double i.e. 60 threads. However the use of WebRTC completely offloads the processing part from central server as it as peer-to-peer technology. The signaling server is used for peer-discovery, in simple words signaling server contains a list of all connected peers, any client device requiring live streaming can query the list to find a suitable streaming peer, once the peer is identified, the communication between client device and peer is established directly, thus there is no server involvement, because WebRTC is peer to peer, it offers higher bandwidth and reliability. The detailed explanation of streaming service and working procedure is explained in the later sections. The input streams for Node Media Servers are from cameras installed.

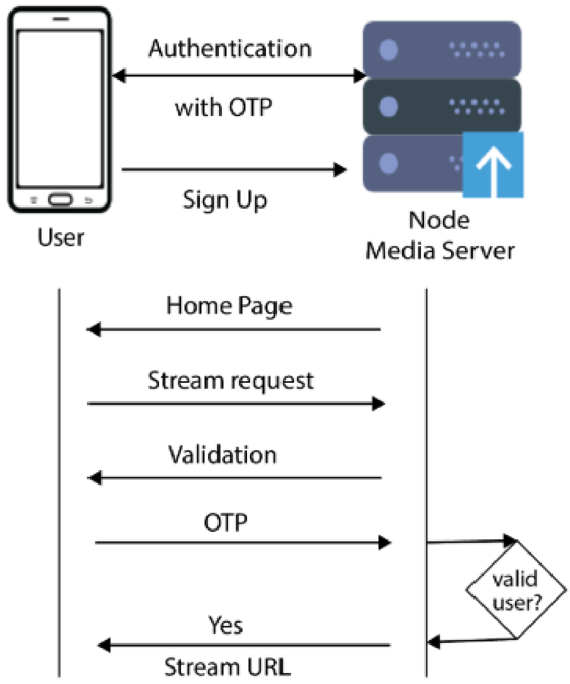

Fig 2. User Authentication

On the client end, the presence of heterogeneous devices are addressed through a PWA (Progressive Web App). The PWA is a web app that can be used as an android app on android device, as an iOS app on iOS device and behaves like a website on browser, because of PWAs we do not require the implementation of the application on all these platforms separately. The client app is used by relatives and associates of the patients. The major focus here is on security, only the intended people should be given access to the streaming service. The security is established using a two factor authentication scheme as shown in Fig 2.

First, the client requests for the stream. The server validates the client's credentials and sends OTP to registered phone number, the OTP system is implemented using a simple messaging service. The client enters the OTP and validity is once again verified. If the OTP is valid, the server can generate two types of URL, if the client has requested for one way communication a HLS live stream URL will be created, if the client has requested for two way communication, the corresponding streaming peer is identified and direct connection will be established.

Another design principle is to support faster integration with existing systems in the hospital, since REST is a portable protocol, one has to just write data pipelines through which patient data and other related metadata can be consumed.

To ensure efficiency, the adaptive streaming technology is used. The HLS protocol provides a good support for adaptive streaming. Adaptive streaming ensures video streaming irrespective of the network conditions by adjusting video quality based on the available bandwidth, similar technology is being used by YouTube and Netflix to provide optimal streaming of videos and improve network utilization. Adaptive streaming in HLS is supported by generating a playlist file (m3u8 file). This file contains a list of optimal video qualities (720p, 480p and 360p) and their respective bandwidths. To select the quality of streaming, it is the responsibility of client to tell sever about the available bandwidth, the video rendering library JW player automatically does that. Fig. 3 shows abstract view of streaming service.

Streaming Services: This section explains streaming services in depth[28].

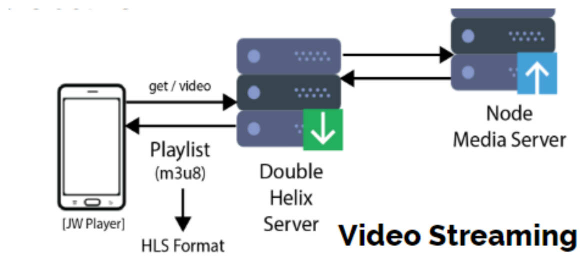

Fig 3. Abstract view of video streaming

There are two types of streaming techniques that we need to understand to choose the one that best suits our solution.

1. Progressive Video Streaming: This protocol uses HTTP over TCP which was very popular for online content viewing due to it being very simple to implement. The video playback starts as soon as the client starts downloading the segments of the media, but before playing the video, the client needs to choose the appropriate video resolution and if the internet speed drops mid playback, the client experiences stuttering. Many features such as fast forward, rewind, seek playback isn't supported.

In simple words, A progressive video stream is simply one single video file being streamed over the internet. This type of file is often an .mp4 but can of course be in many different formats. The progressive video can be stretched and squashed to fit different screen sizes, but regardless of the device playing it, the video file will always be the same.

There are two immediate problems that you will find if you use progressive streaming. The first is quality. Obviously, a video that is only 1280 x 720 will never play at correct quality levels on a screen that is 1920 x 1080px. It will be stretched, and you will see pixilation. The second is buffering. (Buffering is what we call it when the video pauses.) If the users have a poor quality internet connection, and cannot download the video stream quickly enough, then the video will need to pause, wait for more data, and then start again. This makes watching a video horrible for the user. This situation is very common, especially on mobile devices, where the connection can vary greatly depending on the user's location. In order to overcome these shortcomings, we need to use Adaptive streaming.

2. Adaptive Streaming: The quality situation is quite simple. Adaptive streaming allows the video provider to create a different video for each of the screen sizes (or devices) that he or she wishes to target. Buffering happens when a user is unable to download a video file quickly enough to keep the video playing. Most videos play at 24 frames per second, so the internet connection needs to download at least 24 frames every second to avoid buffering. Adaptive streaming can resolve this situation by "adapting" to the speed of the user's internet connection. To explain that in very simple terms, a small video can be downloaded faster than a large video, so if a user has a slow internet connection, and adaptive video stream will switch to a smaller video files size to keep the video playing. The next concept to understand is the "adaption". These settings, and decisions about which video is best for each specific user can be changed from second to second. This means that as users' internet connection changes, the adaptive stream will switch back and forth between video qualities. How does this magic happen? This is achieved with the use of segments. Segments are really at the heart of adaptive streaming.

When a video file is encoded to adaptive format, it is broken up into segments. These are short snippets of video, often set to 4 seconds long (although they can be longer or shorter). At the end of each 4 second segment, the Player can switch to a different video file if necessary.

2.1. Push-Based media streaming protocols: The client and the server establish a connection, the server sends the packets to the client until the client stops the session, the server also maintains the state information and listens to client regarding the state changes. These protocols generally use Real-time Transport Protocol RTP specified in RFC 3550. These protocols change the encoding bitrate of the media according to the bandwidth of the client, this ensures the optimal use of the network resources, but if the client has a good network the bitrate encoding of the video increases above the actual bitrate of the stream as a result it may result in over utilization of the resources. An example for push based media streaming is 3GPP streaming fig 4.

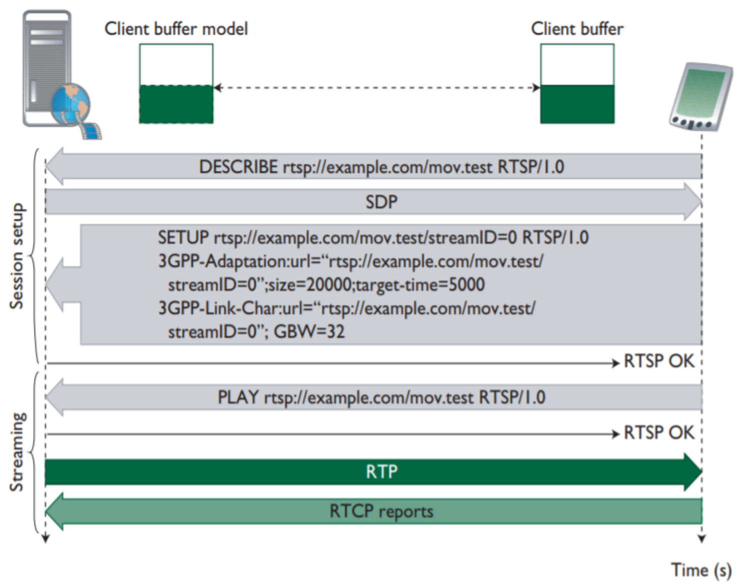

Fig. 4. Push based media streaming

2.2. Pull-Based media streaming protocols: The client is the main entity in this protocol as it requests the media from the server, depending on the bandwidth available to the client. The server does not maintain the state information like push-based protocols and the entire bandwidth of the client is not utilized. This is an extension of the progressive streaming protocol which was widely used and extended to support adaptive streaming. Fig 5 shows an implementation of the pull-based media streaming protocol.

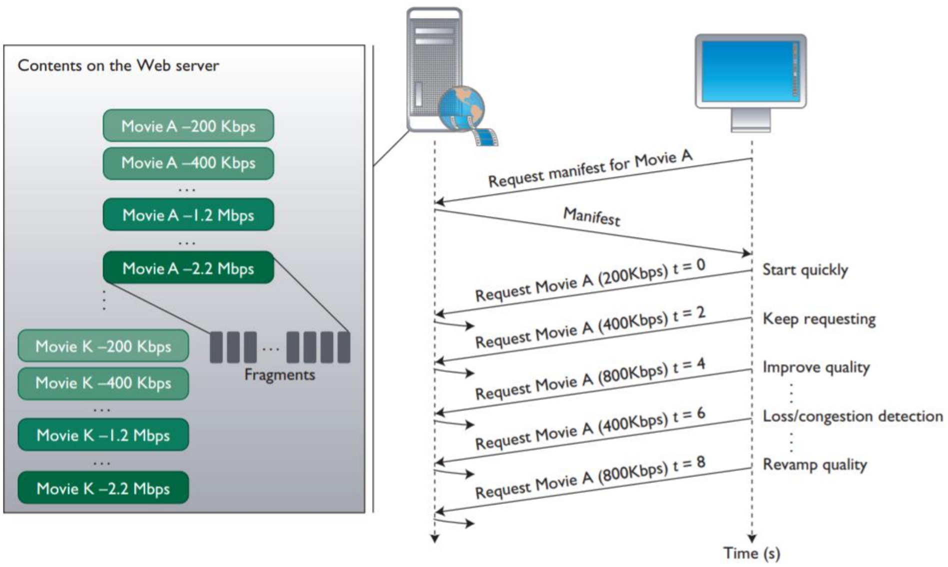

Fig. 5 Pull based media streaming protocol

This protocol uses bitrate adaptation to prevent buffer underflow, here the media is divided into segments and each of which is encoded in different bitrates and can be decoded as necessary. The media fragmentation techniques differ from each implementation but the basic principle of constructing the fragments remains same.

IV. RESULTS

The proposed software system is developed keeping the user's data security in mind, so the entire application will be running locally on the hospitals servers. A traditional client server design pattern is followed wherein the camera input streams are remuxed / transcoded by using our node media server, which uses ffmpeg tool for real-time media transcoding. HLS is used for one-to-many real-time broadcasting, which adjusts the video streams bitrate and resolution to provide buffer less playback to the end user. The web application is built using NodeJS in the backend and reactjs for the client UI, this combination is proves to be very flexible to add new features, secure and reliable. MongoDB is used for the persistent database. Each and every technology used is very fast, reliable, scalable and can handle high I/O.

This system is very helpful for the relatives of the patients who are very far away, or it is inconvenient for them to visit the hospitals frequently, to see the patient easily. This also prevents any additional infections which take place in the ICUs and also facilitates rapid recovery of the patients as they are disturbed less frequently. The additional revenue module of the product helps this system to be self-sustaining and may also provide additional revenue to the hospital. The guardians/relatives can also see the patient's medical documents at a single unified dashboard. The WebRTC module is used for the Conference calls between the relatives and doctors / between relatives as well.

Further this application can be extended by adding an additional e-commerce module, which allows the relatives to buy gifts for the patients as soon as they get discharged from the ICU. Machine Learning can be implemented for the toggling for the video streams, where the stream can be toggled off when there are procedures being done on the patient.

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