ANALYSIS AND DEVELOPMENT OF FRAMEWORK AND MODULES FOR MAMATA (MEDICAL) CYBER PHYSICAL SYSTEM USING LARAVEL AND CLOUD COMPUTING

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ABSTRACT

In hospitals and clinics, MCPS (Medical Cyber Physical Systems) systems are used to give patients customized, tailored and high-quality health care. It embraces the potential of embedded software and network connectivity. Many countries Health Scientists and policy makers perceive the products of MCPS as a one-stop solution for digitally equipped healthcare systems. The Proposed MAMATA (Medical Data Access for MAternal Treatment in rural Area) cyber physical infrastructure has evolved from this need to provide for the management and sharing of health data using the new MCPS technology solutions. This paper is focusing on one of the neglected but Severe problem of the world i.e. of Health data management of maternal women for pre diagnostics information access by maternity hospitals and maternal women too. This can be answered by using our proposed MAMATA Cyber Physical System based Server empowered by Laravel technology and Cloud Computing.

Keywords: Cyber Physical system, Maternal Medical data, MAAMATA National server, Laravel, LaraAdmin

I. INTRODUCTION

Medical cyber-physical systems (MCPS) are life-critical, context-aware, networked medical device systems that participate in the care of a patient collectively. In hospitals, such technologies are increasingly used to provide high-quality ongoing patient care in complex clinical scenarios. There have been numerous challenges facing the need to develop complex MCPS that are both secure and effective, including achieving high levels of system software assurance, interoperability, context-aware decision support, protection and privacy. MCPS explicitly combines the computing power and the contact modes with the physical environment [1].

Recently, the two main developments in medical devices have been a high degree of dependency on software-defined functionality and broad network connectivity. The former development means software plays an ever-increasing role in overall system protection. This means that instead of stand-alone machines that can be developed, used individually to treat patients, distributed network medical devices can track and regulate various aspects of the physiology of the patient at the same time. MCPS aims to enhance patient care efficiency by delivering customized treatment with the reference of patient. The need for such approaches provides new possibilities for MCPS and more generally, embedded technologies and CPS researchers. While in implementing this approach there are many Problems are present. One of the key issues in the creation of MCPS is the guarantee of patient’s data protection.

The organization of this paper starts with various MCPS Challenges present around, Concept of MAMATA CPS Framework, Development of MAMATA CPS NMDBS (National Maternal Database Server) with its Users working flow, Comparatives of General CPS and MAMATA CPS for maternal women’s only. Lastly this paper highlighted the Technology stacks used and User Interface details of MAMATA CPS Product.
II. MEDICAL CPS CHALLENGES

In the Medical field, Remote Patient Monitoring has been proposed by many researchers [2]. That's restricting the whole medical ecosystem consideration. On the other hand, MCPS promises the opportunity to monitor patient symptoms remotely and take action regardless of the patient’s location. MCPS-enabled sensor data can be processed in a server and made available to clinicians. The large amount of data obtained from various of medical sensors must be processed and handled. Database management systems should be effective and secure. In addition, sensor networks collecting patient data are limited in storage space to store huge quantities of data. The cloud-based database server can solve some of these problems. Valid hospitals or individual patients can access the cloud infrastructure from anywhere anytime. Since medical data may provide invaluable insight into actions (treatments) required to save a patient's life, all data should be readily available and accessible from anywhere to approved medical staff. Some CPS-based works have attempted healthcare applications [3-4]. Furthermore, most CPS researchers reported that CPS architectures should be used to capture a variety of physical details, accurate data analysis, event detection, and security [5-6].

However, our issues focused here are very different than MCPS. It has been found that, world has overlooked maternal women's problems in South Asia, particularly during their pregnancy. These problems are discussed below

Problem 1-

According to World health organization (WHO) report [7] facts; maternal mortality is unacceptably high. Everyday about 830 women die from pregnancy or childbirth related complications around the world. In 2015, it was estimated that roughly 3,03,000 women died during and following pregnancy and childbirth. Almost all of these deaths occurred in low-resource settings, and most could have been prevented.

Problem 2-

According to Ministry of health & family welfare, Govt of India January 2013 report, India accounted for 19% of all global maternal deaths and nearly 20% of the world’s child death. The hemorrhaging and anemia accounts for 38% of all deaths followed by infections, abortions, improper access of medical information. In rural/remote areas, women’s are not aware about what care need to be taken during pregnancy and post-natal follow up. The root cause of these problems is due to the unavailability of hospital/pathology/blood bank. Also, there is no good healthy communication network from hospitals to patients and vice versa. Table 1 shows miscarriages and its percentage as per report of Ministry of Health and family welfare, Govt of India [8].

<table>
<thead>
<tr>
<th>Sr. no</th>
<th>MISCARRIAGES TYPES</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Haemorrhage</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Sepsis/infections during pregnancy</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Hypertensive disorder</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Blood infection</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 1. Miscarriages/ Maternal deaths due to lack of information by mother.

The above stated problems occur in developing and undeveloped countries. There are many reasons behind it viz. woman's staying in remote/rural areas doesn’t visit to hospital for regular, important checkup. Most of the hospitals/pathology labs do not maintain the women’s diagnosis data properly. Hence it is difficult to find out previous health status; if she approaches to new hospital, due to any problem occurs because of vaccination, drug side effects, infection etc. and many other maternal issues.

Moreover, these conditions are largely preventable and once detected, they are treatable too; if adequate maternal treatment data/information and follow ups is provided by Medical CPS (Cyber Physical System) by providing instant access to hospitals, even if patient switches to any new hospital. To address all above issues, MAMATA Cyber Physical system found to be proposed as a solution to MCPS problems of Maternal Women.
III. MAMATA CPS

A. MAMATA (i.e Medical Data Access for Maternal)

Treatment in rural Area CPS: it is coming out as One stop solution to MCPS challenges. The Term MAMATA also has famous meaning as per Sanskrit and Hindi language as “an emotional/lovable feeling of maternal women or mother for her newborn baby”

B. MAMATA CPS Environment/Concept Flow:

MAMATA Cyber Physical System Structure is proposed to address maternal treatment-related issues discussed above. These treatment issues emerged because of many procedural roadblocks, i.e. insufficient access to hospitals, pathology lab, maternal women and many more. MAMATA CPS proposes its own MAMATA NMDBS server, i.e., MAMATA National Maternal Database Server, which seeks to resolve many maternal care problems. This server side connects three major components: i) Maternal Hospitals ii) Pathology labs and iii) Maternal women. MAMATA NMDBS server collects data from respective maternal hospital and/or pathology laboratories and update its database against the respective maternal women account. Each maternal women account has unique credentials for access at the level of maternal women and/or hospital, pathology laboratories whenever needed. Earlier there were few attempts have done to address some of these issues and develop such servers (EHR), but they had health records for general public purpose; additionally, such servers lacked uniformity in health data formats and standards across hospitals, labs and countries regions. Generally, many hospitals and pathology lab used to maintain their own formats of general health record that can be challenging for other gynecologists, maternal hospitals and new pathology labs. This also reveals that suitable framework for EHR based servers have not been implemented so far.

The MAMATA NMDBS Server answers above issues with focus solely on Maternal women’s only with uniformity in health records with standardized and fixed formats that enable the healthcare ecosystem to develop and provide satisfactory solutions to the world health organization’s problems. MAMATA NMDBS server is the best solution for those countries where maternal and child deaths are more, specifically, in India (or developing countries) wherein many women’s need to change hospital or doctor during maternity period for the multiple reasons, viz i) shifting from husband’s house to mother house in the middle of maternity treatment, (India/South Asian family tradition), ii) Inappropriate medical facility in initial hospital, and iii) Environmental issues.. However, MAMATA NMDBS Server-side application faces some challenges which we have considered during its development and discussed in the following.

C. MAMATA CPS Challenges:

Building MAMATA CPS involves many major challenges, including:

1. Software of higher assurance – In medical equipment, software is playing a major role. Software now performs several functions historically implemented in the hardware – including security interlocks. To ensure the safety and productivity of MAMATA CPS, highly confident software development is necessary.
2. Interoperability: As medical devices have communication interfaces, it is important to ensure that integrated medical devices are safe, reliable, secure and should be possible to get accredited.
3. Protection and confidentiality: MAMATA CPS data are highly important to gather and handle. Unauthorized access or misuse of this information may have serious consequences for the patient in the form of privacy-loss, discrimination, misconduct and physical harm. Preserving MAMATA CPS protection is important.
4. Stress Testing: As per survey, no other MCPS system performed stress testing for networking. MAMATA CPS is mainly focusing on stress testing to handle heavy network load by discovering breaking points and areas for improvement. Checking network limits internally and externally will give an idea of what it takes to put network down. This can also happen if too many people transfer big files through the intranet or LAN pieces. Simple CAPTCHA might thwart attacks, but sometimes it’s not that simple. Attackers can create malformed packets and send them to extremely large exposed ports. Being able to withstand this form of attack is important for any company that relies on the internet. MAMATA CPS worked on this problem and created trustworthy framework.
5. Certification: MAMATA CPS needs a cost-effective way of showing the reliability of medical device software because of its dynamic and secure design. Certifiability is therefore an integral prerequisite to address the ultimate feasibility of MAMATA CPS and an important obstacle.
D. MAMATA CPS Server Framework:

While studying any CPS system, it is found that thousands of CPS components need to setup with its own technical requirements. Any Framework who deals with content/data management should take care of all technical, operational, strategic and/or collaboration solutions [9]. Wherein focusing on only technical priorities results in lack of functional/logical sequence between the components of CPS.

Figure 1: MAMATA CPS foundation dependencies.

MAMATA CPS complements this with the Semantic and Technological Growth approaches Our Proposed server framework is built on three verticals 1. Technical 2. Procedural, and 3. Semantic/practical. This system gives better responses when feeding the user's data. Here to protect the semantic and procedural flow, MAMATA CPS offers unique privileges to every registered and approved users as per their role i.e. Super admin, Admin and end user. The Hospital Units or Pathology Labs may send maternal woman's data as per the data formats, whereas the same Hospital units/path laboratories have been controlled and monitored by the upper-layered Monitoring Person named Superadmin. Figure 1 shows the total CPS foundation flow. Where this system's procedural workflow is elaborated in Figures 2, 2.1, 3, and 4.

IV. MAMATA CPS NMDBS SERVER

We are proposing and designed as well, first edition of MAMATA NMDBS (National Maternal Database Server) that has the ability to cater major problems of Software of higher assurance, data uniformity, data security Procedural Roles flow, and eventually system stability as discussed above in MAMATA CPS challenges. Proposed MAMATA NMDBS Server based on Laravel's Technology Stack in support with newly designed Open source Framework named LARADMIN i.e., the LaraAdmin interface stack [10]. Currently MAMATA NMDBS server is up for testing (www.mamataserver.in). The first page of above link of MAMATA NMDBS server is shown in Fig. 3.

A. MAMATA NMDBS Server features-

Technical- Deployed on Digital Ocean Cloud, Development based on open source technology. It is Powered by Laraadmin framework. It doesn't have dependency of APIs like OAuth2, REST API.

Functional features- Three major user verticals named Hospital Units/Gynecologist Account, Maternal Women Account, and Pathology labs.

B. MAMATA NMDBS Server Working Operation:

- Rights/Role Workflow:

The objective of MAMATA NMDBS Server to update the maternal treatment care information against respective maternal women’s account by the Concern Authority of Hospital /Pathology lab (may be doctor or any valid representative). With this reference MAMATA NMBDS Server User’s Roles are categorized as Super Admin, Admin and End User. Every Role defines different rights access of account information. This server allows any user to open/register their account against unique national registration number (e.g. UIDAI/Aadhaar No in case of India). The User with "Admin" role (referred to as the Regional hospital/pathology lab authority) has access to update and submit the respective maternal woman’s care information as per MAMATA NMDBS server prescribed format, and that too only after verification by super admin (Super Admin is officer/authority deputed by concern countries government). Wherein the maternal women have End User rights, and she can only be allowed to observe
her maternal treatment data on her account; Against submitting valid login credentials to access her account. The entire flow of Roles and Rights access is as shown in Figs. 2 and 2.1.

- **Super admin Role/Workflow:**

Super Admin’s role is very important in MAMATA NMDBS Server. As shown in Fig. 2.1 below, any new hospital/pathology lab or maternal related account activation is controlled and monitored by Super Admin. For example, if the new hospital/pathology lab needs to register themselves, they need to show their legal registration no, NABH no number (i.e. National Accreditation Board for Hospital and Healthcare Providers, NABH number, in case of India). Similarly, decision on new account creation/activation of maternal women’s account shall also be taken up by Super Admin against successful validation and supporting reports of hospital/gynecologist. However, the said conditions applicable only to new account registration of hospital and/or End User’s first pregnancy case.

If the maternal woman already has MAMATA account on the MAMATA NMDBS server and has arrived for second or subsequent pregnancy treatment (Fig. 2.1), then super admin will ask for unique account national registration number, validate it and then may allow Admin to update her maternal care data for the next pregnancy track. Conclusively, it is important to remember that one End user (maternal woman) has only one account with one specific national registration number in her lifetime and her all pregnancy related information is reported against the same one account. The first registration window of MAMATA account is as shown in Fig. 3.

![Figure 2.1. Workflow flow module for Super Admin.](image-url)
Role of hospital unit/Clinical/Path Labs:

Hospital Units/Clinical/Path Laboratories play a key role in Servers workflow. They act as a Nodal Officer or Delegate for MAMATA CPS Operations. The authorized hospitals/ Clinics/ pathology lab Administrator is responsible for any new request for account generation, online reporting and/or information update. As shown in Fig. 4, the user with Admin rights is responsible for updating maternal women’s health and/or clinical data against her account. This workflow is subject to maternal women’s account existence. If the account does not exist, Admin can submit request to Super Admin for new account which will be generated after super admin approval.

![Diagram](image)

C. Role of hospital unit/Clinical/Path Labs:

The actual user interface for maternal data updatation has been shown in fig. 5. This figure taken as actual screenshot of MAMATA NMDBS server portal UI. In recent study, various health monitoring systems were suggested with end to end standards and are more relevant to general patient monitoring[13]. Healthcare systems for maternal woman is untapped with common standards/guidelines viz: HL7 [11] or EN 13606. It is important to mention that the MAMATA NMDBS Server architecture, data update parameters format has been designed and followed as pert most of the guidelines mentioned in the HL7 and EN 13606 standards of health records [12].
Closely related research has suggested some standard IOT-based platforms [14] for health monitoring systems, whereas MAMATA CPS system plays a dual role in storing and tracking health data in response to user query requests, thereby eliminating the need for multiple monitoring servers. This multitask server capability also increased interoperability across the domain. We have studied and worked on the challenges proposed in several general cloud based health CPS [1] [15] [16] [17] and tried to overcome the same in MAMATA CPS implementation, the same are discussed below in Table 2 and Chart 1.

**Table 2: Comparison of General Health CPS and Proposed MAMATA CPS System**

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Features/Challenges</th>
<th>General Health CPS</th>
<th>MAMATA CPS (for Maternal Women)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>User Identifiers/ rights</td>
<td>Partial</td>
<td>YES (Complete)</td>
</tr>
<tr>
<td>2</td>
<td>Architecture support</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>3</td>
<td>Large scaling</td>
<td>Only discussed</td>
<td>Implemented by cloud</td>
</tr>
<tr>
<td>4</td>
<td>Data Modules Manager</td>
<td>Not available</td>
<td>YES (Available)</td>
</tr>
<tr>
<td>5</td>
<td>Heterogonous data collection and management</td>
<td>Partial</td>
<td>Taken care with unified standards</td>
</tr>
<tr>
<td>6</td>
<td>Functional and reference model</td>
<td>Limited (Vary by case to case)</td>
<td>YES (end to end)</td>
</tr>
<tr>
<td>7</td>
<td>Application UI Interface</td>
<td>Heavy to use</td>
<td>Light/User Friendly. (LaraAdmin)</td>
</tr>
<tr>
<td>8</td>
<td>Coding dependencies</td>
<td>YES (one Language dependent)</td>
<td>YES (Flexible to adopt other language)</td>
</tr>
<tr>
<td>9</td>
<td>Standards Support HL7/EN13606</td>
<td>Partially</td>
<td>YES (Completely)</td>
</tr>
<tr>
<td>10</td>
<td>Reliability/Safety</td>
<td>Discussed</td>
<td>YES</td>
</tr>
<tr>
<td>11</td>
<td>Medical Device interface support</td>
<td>Limited (Depends protocol used)</td>
<td>YES</td>
</tr>
<tr>
<td>12</td>
<td>Data Privacy</td>
<td>Limited</td>
<td>Yes (very strong)</td>
</tr>
<tr>
<td>13</td>
<td>Attacks /security</td>
<td>Limited</td>
<td>YES (prevention from CSRF/XSS)</td>
</tr>
<tr>
<td>14</td>
<td>Response Time</td>
<td>Not discussed</td>
<td>Very Fast</td>
</tr>
</tbody>
</table>
As mentioned in table; MAMATA CPS provides unique database module manager component to handle every workflows of Super admin, Admin and End Users. This feature makes MAMATA CPS more unique and separates from General CPS currently available.

V. MAMATA NMDBS SERVER IMPLEMENTATION

i. About Laravel and LaraAdmin-

MAMATA NMDBS Server is designed and developed using Laravel platform and unique Admin panel framework designed named LaraAdmin. Laravel is One of today's most common PHP frameworks and it is solely intended for the production and licensing of Model View Controller (MVC) applications. Laravel has proven to be the preference of the majority of developers from around the world, from personal use to workplace ventures. Laravel offers the means to make work in simple ways. Till date several content management systems and customer relationship management (CRM) has used using laravel, whereas adoption of laravel platform for development of CPS Server in Medical domain is first time initiated i.e for MAMATA CPS NMDBS server. Laravel found to be one of most suitable platform for MAMATA CPS design development.

About LaraAdmin: it is acts like flexible Content Management system and/or admin panel framework designed and used for MAMATA NMDBS server. Using LaraAdmin; MAMATA NMDBS Server offers easy customization at admin panel and best in class features like-

a. Module Manager that help to create various data modules with table schematics/formats.

b. CRUD Generator: MAMATA CPS NMDBS Server has facility of CRUD (Create, Read, Update, Delete) data updates. For example: data view (to end user), controller, migration, test cases (to admin).

c. Roles and Access: we have created modular access for roles; this allow Module Views, Edit, Delete Accesses. We used Zizaco/Entrust packages [18] for support.

d. Upload manager: It allow to handle the file database and also It also protects users data files with layer of access control and file settings.

e. Menu handler: it helps super admin to control the menus without entering to code backend. This is most useful feature for super admin to control menus of end user of MAMATA CPS NMDBS server. In addition, some other features are also been offered like configuration, field access, code editor etc.

ii. Security Flow in MAMATA CPS:

Security is must consider component for any health care related Application. In recent studies, there are few attempts have done to cater security issues using various cloud-based injection algorithms [19] however Medical CPS is still untouched here. Here during development of MAMATA Server we have adopted multilevel security
threads for data protection and transfer. Our server uses Php data Object (PDO) that protect database attacks i.e. SQL injections. Additionally, our server designed to fight against CSRF (Cross Site Request Forgery).

MAMATA NMDBS server framework has provision to support HTTPS to prevent data request attacks when MAMATA server initiates to exchange sensitive information. Moreover, the server avoids XSS attacks [20] as well. This all security provisions support MAMATA CPS more secure.

iii. Models creation –

MAMATA NMDBS server has capacity to make various models (i.e factories) using its model feature. Models feature allow MAMATA Server to perform data logic and database manipulation like – retrieve data, insert, update, and delete. Model factories provide a convenient way to create models for testing and seeding your database. Following snippets of code explain the factory how a default model should look. This model code has been created in database. With Directory - //database/factories/ModelFactory.php

iv. Sessions management -

With facility of model, it is important manage the sessions of each model and users. We have created various sessions to protect functionality of every user’s role viz Admin, End user. We are using session driver to manage the sessions, who initiates, monitor and control the session according to their categories. Session driver follows active time of user, expiry or timeout status, model files path and database location. This end to end practice make us manage the session efficiently. This means if any user make no operations and become ideal for more than stipulated time, the session ends for that model. Session driver defined as 'driver' => env('SESSION_DRIVER', 'file'), // Default Session Driver

VI. MAMATA SERVER USER INTERFACE (UI)

MAMATA NMDBS Server user interface is categorized in basic 4 activities as mentioned below:

i. Fresh Registration Request
ii. Super Admin /Admin Dashboard
iii. Profile Update
iv. Health data Update

Fresh Registration Request: This UI activity is for the first time registration of maternal women, and hospital/pathology labs accounts. Lara admin interface (UI) for this activity has been shown in Fig. 6.

Figure 6: Registration Activity

Super admin or admin can see the list of doctors, end user’s name respectively at his/her dashboard wherein he/she can see the all fresh/existing account request, in ledger form. it is to be noted that fresh request is listed for approval to super admin account.
Maternal women's basic profile account UI is as shown in Fig. 7. This figure shows base profile of Newly opened maternal women profile after super admin approval. However maternal data can be updated or revised by concern Hospital Unit or Clinical Laboratory with due permission of account owner i.e. maternal women (by sharing unique account credentials and/or biometric verification). The UI Interface of Super Admin/Admin offers to update maternal health data/information with trimester based format of new pregnancy-related data. It should be noted that this health data formats are in relevance to health standard guidelines (HL7) and several criteria need to be updated. Thus, due to its multiple window operation, only the first window of Laraadmin Interface (UI) screenshot is as shown in Fig 8.

Figure 7: Basic Profile view of maternal women’s account

Figure 8: Maternal Women/Mother Profile Activity
VII. CONCLUSION/CHALLENGES/FUTURE SCOPE

In the current 21st century, ahead of different lifestyles, birthrate, mortality, and women's health; the nine-month physiological shifts of maternal women also have major challenges. A maternal woman suffering greatly from her physical changes, use of Medical CPS have proposed the health data record keeping ways; but many of these are still in theoretically proposed and have focus on general health parameter this needs many revisions for implementation. Cloud-based CPS for maternal women solves many issues as we discussed earlier. MAMATA CPS NMBDS server is implemented and demonstrated only for maternal women health data management with many features. Entire MAMATA CPS System is based on the Laravel framework. Its LaraAdmin-based Open Source UI Admin Panel offers easy to use and responsive enough to make it suitable for monitoring and controlling Maternal women's health data during pregnancy. This technical activity would also help not only maternal women, but also hospital and clinical laboratory units in the near future to know the health history of last pregnancy or treatment, even if the maternal women change their gynecologist or clinical laboratory or relocate during pregnancy. There are some future scope opportunities present to make such system more reliable, researchers can check response time of overall system using Stress/Performance testing starts with 100 users to may be 500 users. The security of such system has major scope found, we can test similar systems against few but important OWASP TOP 10 (Open Web Application Security Project) vulnerabilities and make more secure.

Moving ahead; the position of government has its utmost importance, as this may be the operational challenge and may differ by the health policy of the country's government. If governments consider or implement this technological MAMATA CPS system, it can be tailored as required by the health policy of each country. This CPS system has technological scope and provision to configure frameworks for insurance agencies and police departments.

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