Spectral Expansion Method For CPS Dependability Model

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Abstract- *Cyber physical system is an emerging technology that converge communication, control and computation. The application of CPS is same as Internet of Things (IoT) but it is more reliable and safer compared to IoT. The CPS is embedded system that combine dynamic element and network. This dynamic system is used everywhere due to its capabilities such as privacy, security, safety, and reliability. The main challenge in this CPS is maintaining dependability between communication, control, and computing. Due to this capacity, the CPS work effectively. Maintaining dependability in the dynamic system is complex. To handle this complex challenge, the novel methodology to CPS called Spectral Expansion mechanism is proposed. The Spectral Expansion for CPS is develop an embedded system that can maintain dependability of the CPS. They use Markov model and transition probability matrix to predict and maintain dependability before the system is affected. This method is compared with traditional dynamic system.*

Keywords- CPS, Spectral Expansion, Dependability, IoT, Markov model

I. INTRODUCTION

Cyber Physical System (CPS) are combinations of computation with processes physically [1]. Entrenched Computer and network based monitor and controls the processes with feedback loop in which process influence computation and vice versa. The transition of time is implacable and consistency is intrinsic in physical process. Nowadays, these properties are needed for computation and abstraction of network. A CPS is newly emerged technology similar to Internet of Thing (IoT) [5, 3] where the physical processes are embedded to form automatic system as shown in figure 1. The application of CFS is a miniature to the 20th century IT revolution. The application such as Medical devices, traffic control, advanced automotive system, energy conservation, process control, environmental control, instrumentation, manufacturing, water resource, critical power control, and communication system, defense system, distributed robotics, and smart structure. Transportation system can improve efficiency, security and safety by using this embedded process in automobiles. It can also improve the efficiency of military with network based vehicle that could offer significant disaster recovery techniques. In communication system, the cognitive radio can have enormous benefit from CPS based on bandwidth. It enhance the energy power in network control building system. Distributed real-timesystems can interact with actuators and sensors that can change the online social interaction. The impact of any application is huge economically. There must be change in core abstraction. Without these changes in core abstraction, we can't achieve the above specified application. This development is combination of control, computation and communication. Nowadays the computation and communication becomes faster and cheaper capacity, so that we can unity these capacity and object in any physical process. This provide as a basic application for the cyber world link for computing and communicating. The cyber physical system communicate with other device and then only compute or control a task. In these initial research efforts, the CPS create a real time and embedded system that can communicate, control and compute an information.

Compared to general purpose computing, the embedded system is considered to higher reliable and predictable standard. The transition of CPS leads to improvement in reliability.

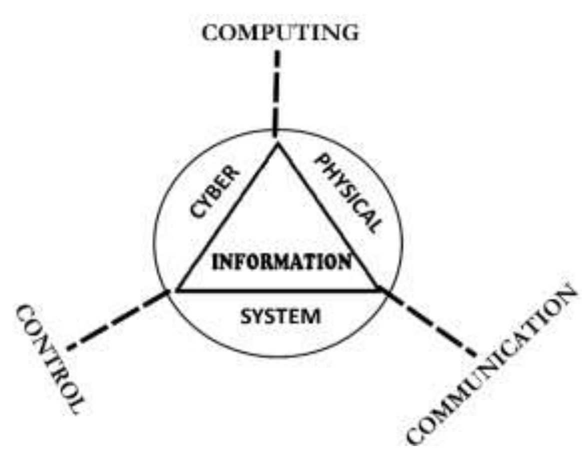

Fig.1 Cyber Physical System

Without this enhancement in predictable and reliability, CPU will not compute into application such as automobile security and safety, medical care and traffic control. Most of the physical process are not entirely predictable. CPS can act dynamically to unexpected condition, will not operate on controlled manner and adaptable to system & subsystem failure. In the physical process, an engineer face many problem related to reliable and predictable. Many system manages to act in predictive nature and reliable but they can't achieve this. In this CPS, the important nature is achieved based on their design. For all digital circuit designer depends on stochastic model to deliver predictability and reliability. The second requirement is should the embedded circuits depends on reliable and predictable. The CPS can also maintain the security, reliability, safety and privacy. This is better dynamic system for managing all type of complex system. The Quality of Service is improved and Service Level Agreement (SLA) is guaranteed using this type of embedded system. The CPS [8, 9] features makes an efficient system that can dynamically solve all problems faced by new technology. All type of new element is installed or embedded in CPS to show the bright future to new technology. It maintains privacy and safety to the information that have been maintained in the CPS.

Networking plays a vital role in cyber and physical system that involves in proper communication elements. The application of CPS [6, 7] as prescribed in above paragraph. It is similar to application and architecture of the IoT. This combination of IoT and CPS simplify the collection, management and processing of large set data, as well as complex data. In this paper, the major challenge is based on networking perspective. The CPS [10] maintains a dependability between communication, computation and control. When the communication network is not proper or safe, the remaining two element id affected. Without proper communication, we can't compute or control a task. The embedded system works efficiently through the information it collects from other device. For example, in traffic management system, proper monitoring and controlling plays a vital role. In that, all the monitors keep on communicate to the server and client about the current scenario of traffics in all routes. If anyone device communication network is jammed, the monitoring is stopped and traffic scenarios is unknown. All the devices are dependable to their servers. The dependability maintenance is the challenge that is going to be handled in this work.

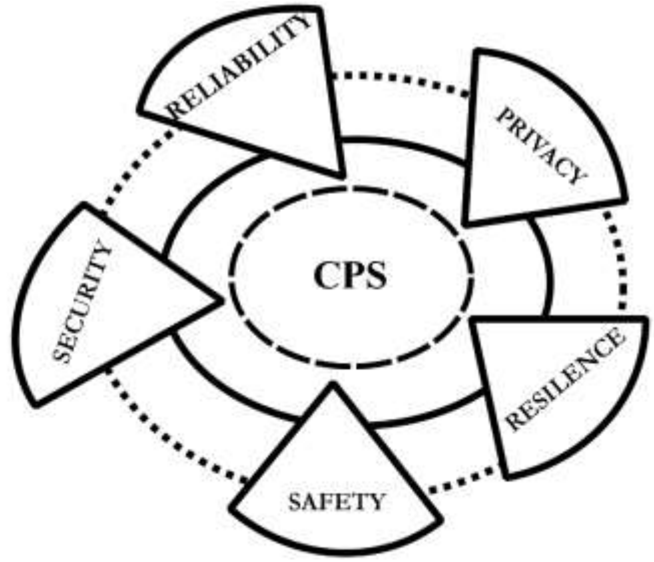

Fig. 2 QoS parameter maintained by CPS

To handle this challenge, we introduce novel mechanism called spectral expansion for CPS. The spectral expansion Mechanism (SEM) is method that solve a complex problem in detailed manner. It zoom in and zoom out the problem and then find a solution for it. It keenly notice and find the root cause of the problem and then remove it. This method is well suitable for maintaining dependability of CPS. The method uses markov model to predict the root cause of the complex situation and dynamically resolve it. The markov model keenly monitors the system and form a transition probability matrix (TPM). The noticed record is analyzed and evaluated to predict the occurrence of dependability between communication, control, and computing. It process the system in prior to prevent the system from dependability occurrences. The spectral mechanism provides better analysis and evaluation compared to other traditional methods. The result from the SEM is accurate and approximate.

The main benefit of this work

(i) Introduce new mechanism for the emerging technology
(ii) Prevent and maintaining dependability of CPS
(iii) Solve complex application of CPS through SEM
(iv) Analyze and evaluate the CPS in accurate manner

The next section describes about the related work, the section 3 implements the new mechanism, and the section 4 shows the experimental analysis. The section 5 ends with conclusion.

II. RELATED WORK

The Cyber Physical system is used in many application and they work efficient in all environment. In this section, the CPS related works are described and the spectral expansion mechanism is also seen.

The author [2], introduced a real time system that design a real-time software for programming field in the system. The CPS design the embedded system and develop an application to prove it. In [11], the author proposed an algorithm to find the frequency of CPU used to decode the video frame. In this method, the power consumption is reduced using CPS embedded system. The deadline decoding is also avoided through CPS algorithm. It reduce the power consumption by using the idle section of CPU. In [4], the CPS determine the standard memory allocation to the machine. In [12], Zhang et al implemented a method to determine the heart failure before it occurs. The embedded CPS monitors the patient periodically and notice their health related measures frequency. Using the measure and their result, the CPS detect Heart Failure (HF) and provide proper measure to overcome the failure. The history of patient and their test results helps the embedded system to find the HF. In [13], the dynamic traffic routing algorithm is introduced to dynamically route the source and destination. It helps the traffic less and accident less path to reach our destination. In this all monitoring device communicate with each other and predict the best path to travel through it safely. In [14], the power consumption of mobile phones is improved by designing a CPS embedded system. This embedded system removes the unnecessary process that consume more power and maintain a limit of power to call or text. The cooling system also embedded in it to reduce power consumption. The experiment results in minimum of 44% consumption of power for running all application and maximum of 75% compared to HAX. In [15], Cha et al proposed algorithm that schedule the work load of task or process. It regulate a unique set of rule that are used to reduce the scheduling CPU utilization. It can enhance the performance of the system. In [16], the author introduced attribute based security measures. It first encrypt the text and decrypt the cipher text. The performance is done in mobile phones where security is to be maintained. It also reduce the size of the cipher text and legally transfer the data to other device.

The type of systems described above are all modelled by two-dimensional Markov processes on semi-infinite or finite strips. In the case of the former, let I; J be the finite and infinite integer valued random variables respectively. These processes occur often in modelling computing systems, communication systems and several other discrete event systems. Significant research work has been carried out in this area [18] and there is a sufficient need for further work. Our primary interest is a sub-class that has the following properties:

(a) The instantaneous transition rates out of state (i; j) do not depend on j when the latter is sufficiently large, say for j >M.
(b) The transition of the random variable j are of restricted size.

There are many sub-types of this that have broadly seemed in the literature. When the jumps of the random variable j, in a transition, are either 1 or 0 or -1, these processes are known as Quasi-Birth-and-Death type. In the QBD process, if the non-zero transition in j are not done with modification in i, these processes are called as Markov-modulated Birth and Death processes [19]. The unbounded no of states complicated makes the clarification of these methods more important. There are numerous methods to solving these models, either by entire class or by sub-classes. In [20], the author have beenscrutinized a Ph/Ph/c queue for the frame work. Seelen's method is imprecise one, the Markov chain is first truncated to a finite state which is an approximation of the original process. The resulting finite state Markov chain is then analyzed, by exploiting the structure in devising an efficient iterative solution algorithm. The second method is to decrease the unbound-state problems involving vector producing function and some unfamiliar probabilities. The third method are then controlled with the help of the singular of the matrix. A comprehensive treatment of that approach, in the context of a discrete-time process with a general M/G/1 type structure, is presented in [17]. The third method, which is the main technique that is applied throughout this thesis, is known as spectral expansion method. It is based on eigenvalues and eigenvectors of a certain matrix polynomial. Some of the ideas concerning spectral method are known [17, 21], but there have not been many examples in the performance literature. Takacs's [21] works concentrate mostly on one-dimensional Markov processes, with one random variable. Neuts [17] does deal with two-dimensional ones, yet has not given efficient computational algorithms for spectral expansion. Some recent works on it have been reported in [26]. An efficient algorithmic implementation for probability distribution is reported in [22]. Earliest numerical results using this solution algorithm are in [24, 25]. The production function and the spectral methods are closely associated. The fourth part method of resolving these models is the well-known matrix-geometric method [23, 17].

From the above related work, the CPS provide security, safety, reliability, and privacy. The dependability is not maintained in the system. They solve the complex problem dynamically. It choose and change its decision based on the information gather from the solider devices. The dynamic feature make the CPS efficient and better.

III. SPECTRAL EXPANSION MECHANISM

The CPS under consideration is a multiprocessor with N identical processors working a common boundless queue job. The processor may break down from one point to another based on their dependability maintenance. Single and dependent failures of processors as well as multiple and independent failures may occur. The failed processor are allowed to process when they undergo some repair process. The single and multiple failures as well as independent and dependent failures are also allowed in this experiment. The system is described in the below figure 3. When functioning state starts, each server process a job at a time, and each process is permitted to occupy only one working states at a time. The services provided is either to repeat or resume with the sampling.

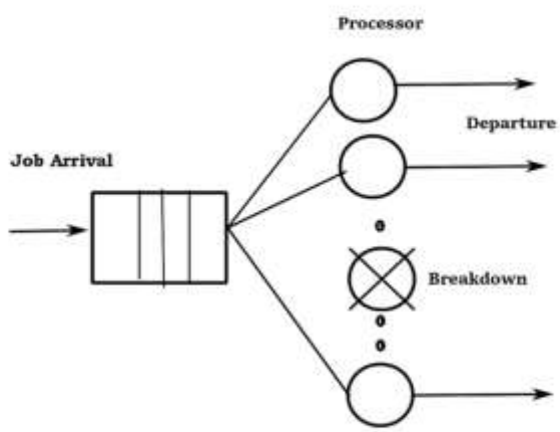

Fig. 3 CPS with breakdown and departure

Let us assume that repair state, failure state and service states are said to be exponential. This CPS is designed by Spectral Expansion Mechanism (SPM). X(t) is considered as working states for the CPS, defines that no of working process running at time t. X(t) differs from 0 to n. Y(t) is no of process or jobs in the CPS at time t. the irreducible Markov model signify the CPS is given by, A={{X(t), Y(t)}; t>0}, with state size {0,1, …., n} X {0,1,….∞}. According to Poisson process, the task are arrived with rate λ_i during the working process X(t)=i. There are two types of failure such as (i) independent break down of individual process at rate £ and their repair rate δ. (ii) failure of all working processes simultaneously at rate $£_0$ and their repair of all process at rate δ_0. When a new task enters or finished, the working state remains the same until the task is a independent task. The dependency is maintained between the CPS to perform the task efficiently. The working state is reflected in transition probability matric (TPM) represented as R and R_j.

The upward one-hop transition are developed by single task arrivals. This is represented in TPM as S and S_j

$$S = S_j = \text{diagonal } [\lambda_0, \lambda_1, \ldots, \lambda_n] \quad j=0,1, \ldots, \infty \qquad (1)$$

The downward one-hop transition are developed by the single task departure. This can be represented as P and P_j. let us assume σ as service state for working server. The departure rate of task at time t based upon X(t) =i and Y(t)= j, and given as $P_j(i,i)$.

Case (i):

If i>j, then all task has a server for execution and not all working processor are engaged. Then the departure rate is $P_j(i,i)= j\sigma$.

Case (ii)

If i≤ j, all working processor are engaged by tasks, then the $P_j(i,i)= i\sigma$.

$$P_j = \text{diagonal}[0, \sigma, 2\sigma, \ldots, n\sigma] \qquad (2)$$

In order to have a detailed study about the dependency between CPS and their task performance, we take three different scenarios of TPM to differentiate the failure, service and repair states.

The three types of scenarios are:

Types 1: In this scenarios, the individual process failure is dependent with rate £ and their repair rate δ. The process are moved from working to not working state while repairing state. Individual failure of the process may affect the other dependent processors. This can be represented in TPM as

$$R=R_j\ (j=0,1,\ldots,) = \begin{bmatrix} 0 & n\delta & & & & \\ \varepsilon & 0 & (n-1)\delta & \cdots & & \\ & 2\varepsilon & 0 & & & \\ & \vdots & & \ddots & \vdots & \\ & & & & & \delta \\ & & & \cdots & n\varepsilon & 0 \end{bmatrix} \qquad (3)$$

Type 2: All currently working states get failure simultaneously. Then the TPM is denoted as

$$R=R_j\ (j=0,1,\ldots,) = \begin{bmatrix} 0 & n\delta & & & & \\ \varepsilon_{0+\varepsilon} & 0 & (n-1)\delta & \cdots & & \\ \varepsilon_0 & 2\varepsilon & 0 & & & \\ & \vdots & & \ddots & \vdots & \\ & & & & & \delta \\ & \varepsilon_0 & & \cdots & n\varepsilon & 0 \end{bmatrix} \quad (4)$$

Type 3: In addition to type 2, the all breakdown processors are forwarded to repair state simultaneously. The TPM of this type is given as

$$R=R_j\ (j=0,1,..) = \begin{bmatrix} 0 & n\delta & & & & \\ \varepsilon_{0+\varepsilon} & 0 & (n-1)\delta & \cdots & & n\delta \\ \varepsilon_0 & 2\varepsilon & 0 & & & n\delta \\ & \vdots & & \ddots & & \vdots \\ & & & & & \delta + n\delta \\ & \varepsilon_0 & & \cdots & n\varepsilon & 0 \end{bmatrix} (5)$$

The threshold limit for dependability is assumed as D. the spectral expansion mechanism for the CPS is effective when j= D-1=n-1.

In these experiment, the working state modification are done only by the matric P_j, it is possible to determine a equation for the steady state distribution on no of working processors, and average execution rate of multiprocessor. Let E be the marginal distribution of no of working server. Then,

$$E= (Q_0, Q_1, \ldots, Q_n) = \sum_{j=0}^{\infty} E_j \quad (6)$$

This is dependability probability vector of matric $X\text{-}D^x$, and can be solved by

$$E(X-D^x) = 0 :Ee=1 \quad (7)$$

The total job executed in CPS is defined as EPe and average arrival loads is ESe. The dependability of the CPS should be maintained to have effective performance. To maintain the dependability, the average arrival jobs should be maintained less compared to job executed.

ESe< EPe (8)

IV. CONCLUSION

The Cyber Physical System is emerging technology where the maintenance of dependability is a challenging task. The dependability is maintained using a novel mechanism known as Spectral expansion mechanism. In this mechanism, the load and service is balanced to maintain the dependability of the system. The dependability lead to failure of n no of systems that are dependent to each other. This types of failure can be prevented by maintaining the dependability of the CPS using the Spectral Expansion Mechanism (SPM). This lead to reduce the failure rate and balance the workload of the CPS and to provide better performance.

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