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Design and Analysis a Real Time Cyber Physical Cloud Computing System

Omar Mowaffak Ahmad Alsaydia[1] & Mohammed Manaf Hameed[2]
[1] Computer and Information Department, Ninevah University, IRAQ.
[2] M.Sc. in Comm. & Computer Networks, Ninevah, IRAQ.

Abstract: *Cyber physical systems (CPS) are mission significant systems that expected to play a major role in the development and design of future smart engineering world with new receptivity that far exceed today's levels of reliability, functionality, usability and security. Due to the limitation of resources, and in order to improve the efficiency and performance of the CPS systems, they are combined with cloud computing system, the new system called Cyber Physical Cloud Computing Systems (CPCCS). These CPCCS have critical care applications such as health monitoring, Smart Transportation Systems and smart cities where the delay and traffic of the systems is a major concern. Therefore, this paper designed different scenarios of real time Cyber Physical Cloud Computing Systems (CPCCS) architecture using OPNET simulator depends on a different cases of clouds, network properties and number of physical devices, then highlight and focus on the performance of the traffic data sent and received between the network elements and the performance of the delay of the data sending in the network of each scenario to evaluate each one and select the proper conditions and properties of the CPCCS network design.*

Keywords- *CPCCS, Cloud computing, Network performance, Real Time, OPNET*

1. Introduction

Computers and communication bandwidth become ever-cheaper and ever-faster, so that communication and computing capabilities will be embedded within all types of objects and structures in the physical environment space. Applications with enormous societal impact and economic benefit will be created by harnessing these capabilities in time and across space. We refer to systems that interlink and bridge the cyber space of computing with the physical space as cyber physical systems [1].

Cyber-Physical System (CPS) defined as a system involving the close integration of the cyber world and physical environments. CPS will contribute to efficiency, safety, comfort and human health, and help solving key challenges of our society, such as the ageing population, limited resources, mobility, or the shift towards renewable energies.

One example of CPS applications is an intelligent home automation for comfort control by using wireless sensor network (WSN) [2]. These sensors which gather, record and process data, communicate wirelessly between each other and other devices. The gathered data analyzed to infer activities in every aspect of daily life, which can give important clues to a person's state of comfortable, relax, restful, and pleasant [3].

In general, cyber physical systems consist of three layers: the physical layer, network layer, and application layer. The physical layer includes sensors and actuators, which perform the control commands from the application layer. While the network layer mainly conveys data between the two other layers, it also manages and processes the data [4, 5].

To improve the efficiency of the CPS systems, they are combined with cloud computing architecture, and are called as Cyber Physical Cloud Computing Systems (CPCCS). Applying Cloud Computing to the (CPS) is useful because it adds new capabilities to the existing system without the need to train new personnel, invest in new infrastructure, or license new software; it needs only minimal management input and service provider interaction [6].

CPCC as an IT Infrastructure allows for the creation of more resilient, flexible, and robust systems that can hold out natural and fabricated catastrophes by allowing distributed and moveable of different computing resources [6].

So that the Cyber Physical Cloud Computing (CPCC) Architectural framework can be defined as "a System environment that can rapidly build, modify and provision cyber physical systems composed of a set of cloud computing [7].

This paper discusses and simulates the performance of a real time cyber-physical Cloud Computing system test bed developed using OPNET simulator. Delay and traffic are two priority characteristics that need to be study, analysis and test. Figure 1.1 shows the proposed scheme of CPCCS.

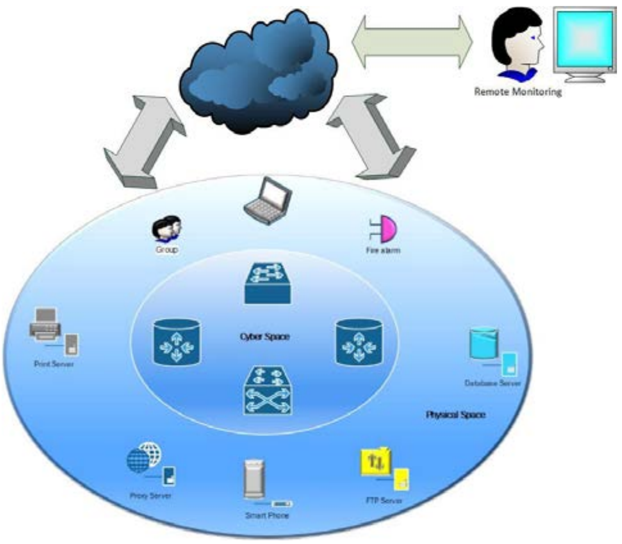

Figure 1.1: Proposed scheme of CPCCS

2. Literature Review

Ara. et. al. [8] introduces a Secure Service provisioning architecture for Cyber Physical Cloud Computing Systems (CPCCS), which combine some technologies such as CPS, Cloud Computing and Wireless Sensor Networks. In addition, they focus on various threats/attacks; security requirements and mechanisms that are suitable to CPCCS at different layers and propose two security models that can be adapted and modified in a layered architectural format.

B. Chen et. al. [9] implements a simple real time CPS test bed RTDS and OPNET. The HIL and SITL capacities of the test bed allow implementation of a combination of hardware, emulators, software and other intelligent electronic devices. Results of a case study simulated in the test bed to study the impact of cyber-attacks on system transient stability are presented. The simple test bed has the ability to accurately model a smart grid and provide a user-friendly modeling experience.

Kanovich et. al. [10] discussed the foundational differences and the impacts on the analysis when using models with discrete time and models with dense time. This study shows that there are attacks that can be found by models using dense time, but not when using discrete time. The study illustrates this with a novel attack that can be carried out on most distance bounding protocols. In this attack, one achievement the execution delay of instructions during one clock cycle to convince a verifier that he is in a location different from his actual position. The paper proposes a Multi-set Rewriting model with dense time suitable for specifying cyber physical security protocols. This paper does not mention to the benefit and advantages of using cyber physical system with cloud computing.

Pawlick et.al. [11] designed a framework for a cloud-enabled CPS that specifies when a device should trust commands from the cloud, which may be compromised. This interaction can well consider as a game between three players: a cloud defender (cloud administrator), an attacker, and a device. This design use traditional signaling games to model the interaction between the device and the cloud, and use the recently proposed Flip It game to model the struggle between the attacker and defender for control the cloud. Because attacks upon the cloud can occur without knowledge of the administrator, it assumes that strategies in both games are picked according to prior commitment. The results contribute to the growing understanding of cloud and CPS controlled systems.

3. Design of the Proposed Cyber-physical Cloud Computing system

Cyber Physical Cloud Computing System (CPCCS) essentially is a CPS system connects between the cloud computing systems and different types of smart physical device networks.

The proposed network design in this paper, which is simulated by OPNET simulator, combines between a proposed physical network distributed in a specific area, and a monitoring and processing center (which can be also a smart phone or personal computer) via cloud. The physical network consists which contain different type of sensors, FTP server, printer server, smart phone and database server, and then connected to each other by switches and router, this network called cyber-physical system (CPS). These devices are smart and intelligent ones, so every device is responsible of covering a defined area and do actions in it according to the conditions and statistics sent to the central unit (Server). This server may send commands to the sensors so the designed network took this issue in consideration to achieve the actual conditions of the traditional networks environment.

In order to improve the CPS network performance, we add a cloud computing system to the CPS. The simulated Cyber-physical Cloud Computing system (CPCCS) tries to provide a realistic and optimum delivery of information data between the virtual smart physical devices (nodes), remote control center and cloud in a multiple scenarios of CPS network configuration, and then study the performance of the traffic between them and the delay according to each network status.

In addition, we study different cases of clouds properties, each case has a specific delivery rate and delay for data within the cloud to achieve and simulate the expected probabilities of the CPCCS network.

It is important to known that the simulated network assumes typical conditions for the sensors and other devices to simplify the simulation because the paper doesn't focus on study the performance on the sensors.

The CPCCS simulated network has the following general setting:

1. The area of the network is (50 Km * 50 Km).
2. The physical devices and sensors are fixed (No mobility).
3. The generated data from CPS and the received one is dynamic and the traffic within the network is random with time.
4. The locations of different network elements are known and the physical devices distributed regularly.
5. Not all the data send from sensor to the central unit need a feedback because some of the readings are just for monitoring.

Also, we simulate three different scenarios of the CPCCS network depend on the number of physical device, cloud type and packet latency as below:

- **Scenario One**

The first scenario obtained in the paper is based on the following assumptions:

1. No. of sensors is 10.
2. Cloud is set to forward as much as it can, i.e. the packet discarding is about 2%.
3. The packet latency is set to 0.001 sec.

- **Scenario Two**

The second scenario of our network assumes the below:

1. No. of sensors is 25.
2. The packet discarding ratio in the cloud is set to 5%.
3. The packet latency is set to 0.005 sec.

- **Scenario Three**

In the third scenario we try to simulate a case of a network when there are a lot of nodes and in this network the elements suffer from the collisions and delay and packet losses so we assume the below:

1. No. of sensors is 500.
2. Cloud's packet discarding rate is set to 10% and this is almost actual.
3. The packet latency is set to 0.05 sec.

4. RESULT

The study makes a comparison between the sent and the received data between (CPS) and control unit, also we studied the performance of the delay within the network for the mentioned assumptions above.

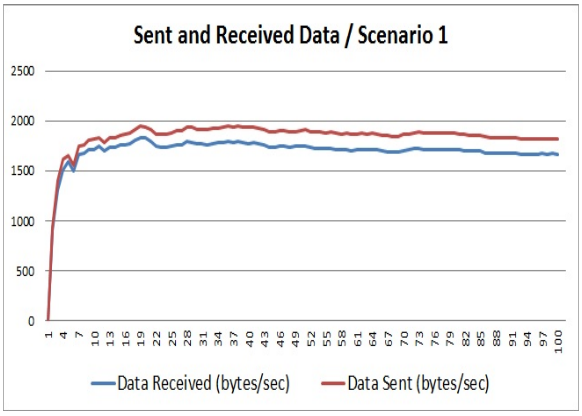

Figure 4.1: The Sent and Received Data transferred in the network of the first scenario

Figure 4.1 shows the difference between the sent and the received data in the whole CPCCS network for the first scenario. The reading of the sent data is about (1800 bytes/second) and of the received data is about (1700 bytes/second) and it's clear that the data rates doesn't high and that is an indication for the number of physical devices and there data transferred. Also we can notice that there isn't a huge variance between them and that is because the low rate of packets discarding in the cloud which has the major responsibility to deliver data in the network.

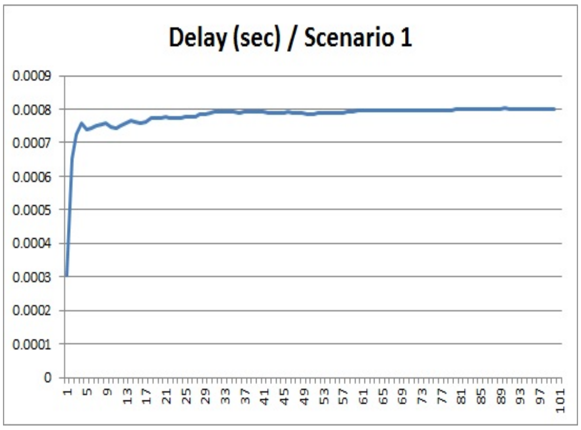

Figure 4.2: Delay performance of the transferred data in the network of the first scenario

Figure 4.2 illustrates the performance of the delay while transferring which is (0.8 msec) and this value is too little according to the attribute of the cloud and the packet latency value and the simple configuration of the network.

We also checked the effect of changing the properties of the CPS network and adding more devices to it to go over the actual and traditional samples as below in second scenario.

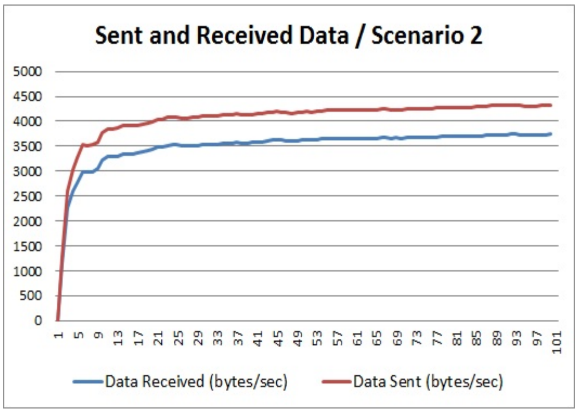

Figure 4.3: The Sent and Received Data transferred in the network of the second scenario

As we can mention from figure 4.3 it's clear that the rates of sending and receiving data are more than the previous case where the sent data is about (4500 bytes/second) and the received is (3700 bytes/second) and that is because of enlarging the network and adding elements to it which effect the amounts of data flow in it.

The other noticeable thing from the figure is the increase in the contrast between the sent and the received data, this is happened because the bigger packet discarding ratio in the cloud which affect the delivery of the data between the nodes of the CPS network as long as not all the sent data from the physical device reaches the central unit and not all the commands delivered to the sensor to do actions.

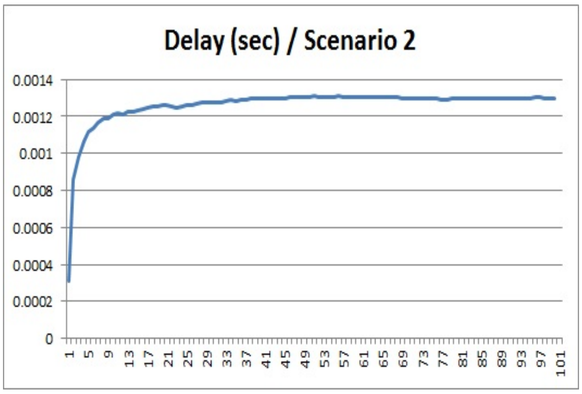

Figure 4.4: Delay performance of the transferred data in the network of the second scenario

The other noticed aspect for this scenario is the variety in the value of the delay, as shown in figure 4.4, which calculated while sending the data between its elements. The delays records here (1.3 msec) and that is related to change the packet latency and to the increase in the number of the physical device which affect the time needed by packets to reach the central unit.

And for the third scenario and according to its specifications the simulation time was very long and the results need a lot of time to be viewed according to high traffic data moved within the CPS network and the cloud specially and that effect on the readings and the performance of the network.

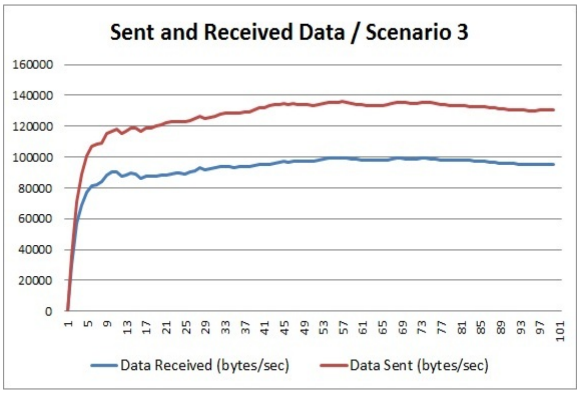

Figure 4.5: The Sent and Received Data transferred in the network of the third scenario

The huge amount of data traffic sent in the CPCCS network is the first impression could notices from figure 4.5, (140 Kbytes/second) is the sent data value and that is an expected value due to the high number of physical devices distributed in the CPS network and control messages and configuration data between the physical devices and central unit and vice versa. The other matter is the difference between the sent and the received data in the elements of the CPS network while the value of the received data here is (100 Kbytes/second) and that's because the using of the large number of physical devices and control and configuration messages transmitted in the network to manage the operation of it.

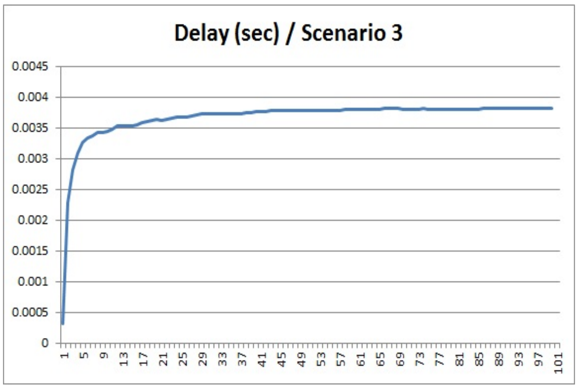

Figure 4.6: Delay performance of the transferred data in the network of the third scenario

Delay performance of this scenario marks a high reading (3.8 msec), as shown in figure 4.6, and this value related to the number of physical devices and the high operation and management needs when the CPS network has a large number of elements and when these elements send and receive a lot of traffic in a few time frequently.

Figure 4.7: Delay performance of the transferred data in the network of the whole scenarios

Figure 4.7 gives us a brief fact about the delay performance in the three scenarios in our CPCCS network design; here it's too clear that the number of physical devices effects on the delivery time of packets and as shown that in the first and the second scenario the value of the delays wasn't too much while it's increased dramatically in the third scenario when we enlarge the CPS network and this is expected because every node send data will need a configuration and routing massages and issues and all of that may reduce the time of sending data from the sensors the central unit by the other nodes and the same thing happens in the other direction.

5. Conclusion and future work

Cyber physical system is introduced on a symbiosis of applications that allow people to monitor and control a wide range of useful applications such as improved energy efficiency, access control, smart cities and health monitoring. In this study, a real time architecture and OPNET modeler used as a simulation tool to simulate \ test the performance of CPCCS network by selecting multiple impacts and scenarios to the data transferring mechanism and the delay factor of to study. The study shows that the increase in the number of physical devices in the network may effect on the performance of it and especially on the forwarding mechanism of the cloud and that will reduce the efficiency of it by dropping some of the data transferred in it and reduce the throughput of the network. The CPCCS network with a static architecture could handle with a specific number of elements and that returns to the possibilities of each node of it, especially the ones that forward and move the data to other nodes, like switches and router and even cloud.

In future work we will study the security and privacy of CPSSC, and then try to introduce a security middleware, which is flexible to be used in cloud computing with cyber physical system. Also, design a user interface and display the information on a map.

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