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Editorial

A note on advances in scheduling algorithms for Cyber-Physical-Social workflows

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ABSTRACT

The Call for this Special Issue received a number of submissions. After a two-phase review process we accepted ten high quality papers. This includes one research survey paper that gives an interesting overview of the privacy aspects in cyber physical social environments. The other papers are related to scheduling algorithms and techniques for CPS-DS workflow applications.

1. Introduction

Cyber-Physical-Social Distributed Systems (CPS-DS) has gained significant attention in recent years [1–3] thanks to increased abilities to model and represent complex relationships between humans, computers, and the physical world (e.g., rivers, roads, power grids, homes, factories, shopping malls, hospitals, etc.) and be able to monitor and actuate based on human and physical world stimuli. CPS-DS use a vast network of interlinked device such as sensors, gateways, switches, routers, computing resources, applications/services to link the cyber world with the physical and humans' social world. The CPS-DS has paved the way to a new paradigms such as the Digital Twins and Cloud Manufacturing.

Due to the inherent nature of CPS-DS, most application developed for CPS-DS are non-monolithic due to the need to integrate several heterogenous devices, computing capabilities and interfaces, digital representation of physical world models, and human-centric computing to address the social human aspects. Such application hence ca be broken down in the form of workflows. For example, consider a Flood Disaster Management (FDM) applications that can be represented as a collection of workflow activities ranging from capturing and analyzing social media and sensor data using a range of programming abstraction models (e.g. message queuing, map reduce, stream processing) to using complex computational models (e.g. hydraulic flood prediction and forecasting) to detect and predict hazardous events (e.g. collapse of road or railway bridge, flooding of public/private assets) in real-time. Such a workflow activity may need to implement computational models for analyzing social media data such as anomaly detection (flood disasters are anomalies among normal tweet messages), clustering (e.g. to combine all the information from different tweets reporting flooded properties in a specific location), and classification (to identify major events such as flood) in Map Reduce (for historical tweets) or stream processing (for real-time tweets) frameworks. Further, the workflow activity to understand the future risk of flood propagation at a geolocation requires the real-time processing of sensor data (micro rainfall radars, rainfall gauges, water level sensors fitted to drainage/sewerage/river flows, rain presence sensors) in a stream processing framework.

Deploying such workflow with a collection of complex activities each with heterogenous requirements such as cyber device types (e.g., sensors, gateways), cyber application services (computational models and programming abstraction models), social data sources (e.g. social media), and ambient physical world (e.g., rivers, roads) is no trivial task. With the ever-growing ecosystem of cyber (50 billion devices connected to the Internet by 2020) and social (e.g., 1.6 Billion Facebook, 1 Billion WhatsApp, and 320 Million Twitter users in 2015) digital data sources, current assumptions that all the storage and processing capacity necessary for workflow processing should reside predominantly in remote datacenters is being challenged. Hence, the traditional scheduling model for provisioning enterprise and scientific computing workflows, needs to emerge or evolve into a more distributed and decentralized CPS-DS scheduling model that can cater for the heterogeneity and complexities of CPS-DS. Furthermore, such models need to cater for the new generation of programmable cyber devices available at the network edge, such as smart gateways, network function virtualization solutions, handheld devices (smart phones and tablets etc.), and smart

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sensors (e.g., cameras and energy meters). These devices at the network edge can offer small-scale computing and storage capabilities for tackling the new real-time data processing challenges imposed by application that are developed as CPS-DS workflows.

Hence, this special issues solicited papers for addressing complex challenges in scheduling CPS-DS application workflows across the cyber-physical social eco system. In particular, the special issue solicited papers on a number of topics ranging from novel performance optimization heuristics for CPS-DS workflows to automated network edge device configuration selection and allocation to performance modelling and benchmarking techniques for CPS-DS to best practices, success factors, and empirical studies of CPS-DS application workflow scheduling and deployments.

Ten high quality papers were selected after rigorous peer-review process. Snapshot of contributions made by these papers follows next.

The paper "Driverless vehicle security: Challenges and future research opportunities" by Torre et al. [4], presents a survey on security methodologies developed to secure sensing, positioning, vision, and network technologies that can be equipped in driverless-vehicles, an important evolution in cyber physical social paradigm. They demonstrate several vulnerabilities in self-driving vehicles and present security challenges of the different technologies integrated in self-driving vehicles as well as the possible countermeasures to address them.

The paper "Moving centroid based routing protocol for incompletely predictable cyber devices in Cyber-Physical-Social Distributed Systems" by Shen et al. [5], propose a novel protocol named Moving Centroid based Routing Protocol (MCRP) for a new type of Cyber-Physical-Social Distributed Systems network named Incompletely Predictable Networks where cyber devices are mobile and move within a particular range/location. The proposed solution allows optimal transmission of data between a sender and receiver by choosing relay node through transmission probability calculated from moving trends of individuals in the network. Through extensive simulations results, the proposed approach has significant improvement in packet delivery ratio and delay in networks with high node density in comparison to AODV and GrD-OTBR.

The paper "Scheduling workflows with privacy protection constraints for big data applications on cloud" by Wen et al. [6], addresses the issues of privacy leakage in cyber physical social system environments and how data privacy can be achieved in scheduling CPS-DS workflows. They propose Multi-Objective Privacy-Aware workflow scheduling algorithm, named MOPA that can provide applications with a set of Pareto tradeoff solutions. Through experimental evaluation in a simulator environment, the proposed algorithm performs better than NSGA-II and MOPSO algorithms.

The paper "Multi-modal Bayesian embedding for point-of-interest recommendation on location-based cyber-physical–social networks", by Huang et al. [7], addresses the point of interest challenges in location-based cyber-physical– social networks (LBCPSNs). They propose a unified probabilistic generative model namely, multi-modal Bayesian embedding model (MMBE), to discover the social, sequential, temporal, and spatial patterns of users' check-in behaviors simultaneously. Using a arge scale evaluation with real-world datasets from Gowalla and Brightkite they demonstrate the proposed solution's significant improvement in precision and recall performance in comparison with five state-of-the-art POI recommendation approaches.

The paper "Joint optimization of function mapping and preemptive scheduling for service chains in network function virtualization" by Yao et al. [8], study the joint optimization on functions mapping and preemptive scheduling in network function virtualizations. They formulate the problem as an Integer Linear Programming (ILP) and propose an efficient algorithm to address the computational complexity of the ILP. Through extensive experimental evaluations, they validate the correctness and efficiency of the proposed solution.

The paper "Perception-enhancement based task learning and action scheduling for robotic limb in CPS environment" by Li et al. [9], address a very interesting problem of smart service robots and how they facilitate services to humans. They investigate the challenges in performing daily life tasks by robots in a complicated cyber physical environment. They propose a solution that enables robots to adapt to highly changing environment. They propose perception- enhanced smart robotic limb that a three-channel perception and a semantic reasoning model that allows comprehensive perception of related objects, human actions and commands, for better adaption and robustness to environment changes. Through experimental evaluations, day to day tasks such as take apple to people and pour water for people are successfully learned and executed with high accuracy and robustness by the proposed solution.

The paper "Internet of energy-based demand response management scheme for smart homes and PHEVs using SVM" by Jindal et al. [10], present a cyber physical social application in smart energy management. They propose a novel scheme to handle the demand response of smart homes and plug-in hybrid electric vehicles. The proposed scheme analyzes the demand smart homes and plug-in hybrids using a cloud infrastructure for reducing the overall load profile of grid. The simulation results tested using PJM benchmark data and Open Energy Information dataset validate the proposed solution's effectiveness in demand-side management of overall load profile of smart.

The paper "ULAMA: A Utilization-Aware Matching Approach for robust on-demand spatial service brokers" by Ali et al. [11], explores on-demand spatial service broker for suggesting service provider propositions and the corresponding time of service to mobile consumers while meeting the consumer's maximum travel time and wait time constraints. They propose Utilization-Aware Matching Approach (ULAMA) which employs a novel provider-centric heuristic for balancing the utilization of providers, and a consumer-priority-based greedy matching algorithm that prioritizes consumers for maximizing the number of matched requests. Experimental results show that the proposed approach acheives the lowest variance in provider utilization while matching all available providers even when supply greatly exceeds demand.

The paper "Economical and balanced production in smart Petroleum Cyber–Physical System" by Chen et al. [12], focuses on petroleum cyber physical systems. They propose a production optimization approach for cyber physical petroleum system that spans the from field production to the social/consumer market. They use a combination of Dynamic Programming technique, Linear Programming technique and Stochastic Programming technique to optimize monetary profit for a single petroleum provider and extend this approach to facilitate optimization across multiple providers.

The paper "Cultural distance for service composition in cyber–physical–social systems" by Wang et al. [13], address the challenges in the representation of user preference of service composition in cyber– physical–social systems. They propose a service composition approach based on cultural distances to improve reliability and satisfaction. Cultural distance is defined as a measure to compute user preference quantitatively and is modelled using a simple mathematical form. Through experimental evaluations using two real-world datasets, they prove that the proposed approach for representing the user preference quantitatively is more simple and effective than other approaches.

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