Systematic Literature Review on Optimization in IoT

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This systematic literature review aims to perform a brief overview on the existing literature on Internet of Things (IoT), which is a very critical technology in the 21st century. A few of the papers deal with the evolution of IoT as a technology in the past 50 century, whereas a majority of the papers deal with the challenges faced in the communication, modelling and deployment of IoT applications which are exploding in their numbers and the diversity of the type of devices.

Keywords— IoT, Cloud, IoT-Cloud networks, Modelling and Deployment of Distributed IoT applications.

I. Introduction

IoT is one of the fastest growing technologies that is ready to affect the masses in the 21st century. It has found utility in a wide array of fields like ecological monitoring, environmental changes, healthcare, smart homes, smart cities….. the list is endless.

But in order for IoT to truly realise its potential, several of the obstacles need to be solved. Due to the large number of low-cost sensors which are extensively used today for collecting and analysing data, new challenges concerning the modelling, communication and deployment of IoT applications need to be resolved. This literature review oversees a few research papers regarding the above-mentioned topics. The topic of IoT-Cloud networks is an active area of research today, given the huge amount of advantages it brings onto the field.

II. Description

A. Graph based M2M optimization in an IoT environment [4]

The number of sensors used by electronic devices is expected to grow by thousand times in the age of smart cities and autonomous driving. Hence, the communication and interaction between these devices is an important and active area of research.

A popular way of modelling this problem, is to consider every machine as a node, and model this as a graph problem (V, E), V is the set of nodes or vertices in the graph, and E is the set of edges/connections between any two vertices in the graph. In telecommunication networks, the ability to communicate with all terminal nodes is addressed by finding a subgraph with least cost, within this whole graph, referred to as Minimum Spanning Tree approach.[1 - 3] But in Machine-to-Machine communication, modelling this as a Directed Acyclic Graph is being explored in this paper.

This paper attempts to map all the machines that communicate within a network as using the concept of isomorphic graphs. Isomorphic graphs are those, whose structure remains the same, even after renaming/reassigning the vertices of the graphs. In M2M communication, irrespective of the distance/position of the machine, the interacting machines can be modelled as an isomorphic graph.

The nodes are first sorted in topological order, and are visited in the same order. The process of finding a node involves calculating and sorting the area and labelling the nodes. The time complexity of this algorithm is $|V|log(|V|)$. This paper also shows impressive experimental results, and can theoretically handle any number of devices that are communicating with one another.

B. CCN Traffic Optimization for IoT [5]

All the smart applications rely on contextual information of the user, like geographical location, temperature, and other physical information for their working. This information is produced by sensors in the device. Hence, the study of communication of sensors is of critical importance today. The communication of sensors is significantly different from the common usage of internet today, in the fact that they are short-lived, push-based and have small contents.

Sensors can produce information in two ways - on demand (when requested by another entity), or proactively send it to the data-consumers on a periodic basis. Sensors communicate using Wireless Sensor Networks(WSN) which are connected to the internet through gateways. Optimal network protocols for IoT devices is an active area of research, although there are de-facto industry standards.

The major types of routing followed in WSNs are : data-centric and hierarchical.

In hierarchical routing, a leader among the devices is elected, who serves as a proxy for data communication. In data-centric routing, communication happens through hop-by-hop communication. This paper advocates the usage of Content-Centric Networking(CCN), because it is supported on a majority of mobile devices and computers(CCNx), and also by sensors running on Contiki. CCN combines the merits of both hierarchical and data-oriented approaches by using a scalable hierarchical naming scheme, and integrates the security and caching by it's design.

C. Internet of Things (IoT): A vision, architectural elements, and future directions [6]

Smart connectivity to the existing networks, and context-aware usage of network resources is an important part of IoT infrastructure. IoT technology is vastly influenced by the devices that communicate with open-wireless networks like Wifi, Bluetooth, Radio Frequency Identification (RFID), etc. IoT devices are used for sensing and harvesting/collecting data from the environment, and it is used to communicate with the actuator nodes, which perform certain actions in the environment.

Ubiquitous Computing: Mark Weiser, who is considered as the father of the modern field of ubiquitous computing, defined smart environment where the sensors, actuators and other computing devices which are seamlessly integrated into the environment of the user in a non-pervasive manner. This is a generic, 'calm computing' approach. On the other hand, Rogers proposed a domain-specific approach to ubiquitous computing, where the organizations can heap the maximum benefit by customising the usage of ubiquitous computing. Caceres and Friday attribute Cloud-Computing and IoT as the two most critical technologies in enabling Ubiquitous Computing [7]

The advancements in Micro-Electronic Mechanical Systems (MEMS) has resulted in the development of low-power devices, which can sense, compute, and communicate data with other devices of the same nature. These types of devices comprise of the Wireless Sensor Network(WSN), which finds applications in delicate ecological and environment monitoring, healthcare, traffic monitoring, retail, etc.

Cloud computing provides a secure, scalable and efficient storage for the vast swathes of data produced by the innumerable sensors. Apart from storage of data, the compute resources provided by the cloud infrastructure is used for performing analysis/processing on the data produced by the sensors and enabling visualization of data through web-based tools.

This paper presents a detailed study on the advancements of IoT since its inception, the various applications/fields poised to benefit the most from IoT, the challenges faced by Cloud-based IoT, the inter-disciplinary technologies that need to converge in order to overcome some of the challenges, etc are discussed in this paper.

D. A Framework for Building a Collaborative Environment in an Open IoT Platform [15]

When developing IoT Objects, collaboration is very important in all types of projects. But, the existing IoT platforms do not have features for supporting collaborative features. Thus, this paper proposes a platform for users to share diverse ideas and data. The collaborative environment enables people to develop IoT-based objects based on an open IoT platform.

For effective collaboration in developing IoT objects, the open IoT platform needs to systematically record, manage, and match the processes of each development. This framework for collaborative environments will play an important role in providing new ways of working and new ways of service. These types of frameworks need even greater emphasis as companies promote the culture of working as a team, which could be spread out across the world.

E. A Study of Internet of Things (IoT) Applications[14]

Internet of Things is the technology and service that generates information (sensors and embedded systems) - acquisition (parts, devices) - sharing (Clyde) - utilization (Big Data). Internet of Things is proving to be important in increasing exports, jobs and is being used a huge plethora of areas. The Internet of Things market has a huge growth potential as it is extended from social infrastructure (utilities, transportation, automation, etc.) and safety management to the consumer sector centered on life services. Sophisticated wireless communication technology is expected to form a huge network connected to all object units as a communication function.

One other important point to note is that, the loT market has a threat factor in that, the inter-industry areas could be ambiguous due to a variety of convergences. For instance, the electrical engineering industry needs to assume that the communication functions can be granted to electrical engineering devices. Second, continuous education and training is essential regarding these electrical properties and construction methods. Not only the telecommunication sector but the electrical engineering sector also needs education and training. Moreover, the advancement of the IoT technology has opened up new arenas of research like security in IoT devices. Since the IoT technology is gaining widespread adoption in consumer tech, it is imperative to ensure that unauthenticated access to these devices cause no type of harm to the end user.

F. Ravel: Programming IoT Applications as Distributed Models, Views, and Controllers [12]

IoT is bringing in the next technological revolution of the 21st century. Many of the IoT systems are complex distributed system applications, and they share a 3-tier architecture consisting of embedded nodes, gateways that connect an embedded network to the wider Internet and data services in servers or the cloud. Yet the IoT applications are developed for each tier separately. Hence, the developer needs to coalesce these distinct applications together. This paper proposes a novel approach for programming applications across 3-tiers using a distributed extension of the popular Model-View-Controller architecture. The main advantages of going with this approach are - data transport, , efficient energy utilization and automatic model synchronization.

Ravel is a new framework introduced in this paper. It allows developers to program 3-tier architecture explicitly, similar to web applications, using models, views, and controllers. It also introduces the concept of space, which binds particular models, controllers and views to a specific devices. The networking complexities between devices are abstracted away by the distributed model which performs automatically synchronization. It is possible to program applications at an even greater scale using Ravel, encompassing the gateways and cloud which are an integral part of every application.

G. Virtual Storage System based on Multiple Embedded Devices in IoT Environments [13]

The paper proposes a virtual storage system based on the multiple embedded devices in IoT environments. The authors propose to construct the storage by reusing the remaining storage space of the existing embedded devices.

The virtual storage system consists of a client, a gateway and multiple embedded devices. The client transmits various types of data to the gateway. The gateway then divides the data transmitted from the client into multiple blocks, and then transmits each block considering the remaining storage space of the embedded devices. The embedded device stores the blocks transmitted from the gateway or returns the current storage information.

The proposed system is designed to reuse the remaining storage space of the multiple embedded devices for storing the client's data. The system is implemented by using the Raspberry Pi3 for checking the feasibility and scalability. A great deal of memory efficiency in the devices is demonstrated through this methodology.

H. Living in the Cloud or on the Edge: Opportunities and Challenges of IOT Application Architecture [11]

Introduction:

IoT technology brought in the sensing plus communication on shared protocols devices, which can provide real-time data regarding the environment. Besides, the availability of low-cost devices has also ushered in an era of performing computations on devices which are at the edge of the network.

This brings in new challenges in non-functional requirements like modelling, deployment, security, privacy, etc. This paper addresses the challenges of deployment and modelling in these situations.

Using powerful edge devices, IoT devices can offload a significant portion of their business logic and processing requirements onto the edge devices. Technical advantages of this new idea are - *lesser latency, lesser communication overhead, provenance detection, privacy and security.*

Examples:

1. **Smart Hospital:** We can have multiple rooms full of sensors like temperature, blood pressure, sugar levels, etc which alert the hospital staff if any of the readings goes beyond the threshold values. Also, a low-cost computer like a Raspberry Pi/Personal Computer may be crunching data from all the rooms for the processing purposes.

2. **Smart Rails:** Every wheel in a train can be fitted with 8-10 sensors to measure quantities like vibrations, torque, etc. The data from every wheel can be transmitted to a small processing unit on a train car. This unit performs some processing and sends the processed-data to a main computer on board the train, which receives data from all the train-cars. There are about eight wheels in every car, and every unit in a train-car is responsible to perform a small amount of computation. Also, the main computer on the train, may perform some computations on the data, and may further send it to a cloud, from where the company can keep track of the states of all the running trains.

IoT Applications:

Deployment and modelling of distributed systems is hard in itself. But the modelling of distributed IoT applications prove even more harder, because of the *large number of devices, their sensitivity to non-functional requirements, their diverse nature and heterogeneity, etc.*

Most often, modelling of these types of IoT applications demands extensive domain knowledge. But, from a deployment perspective, it also needs to be robust to the dynamic changes in the environment. For instance, we must decide what type of data to process on the train and what data to send over to the cloud. But this decision, must incorporate the possibility of dynamic changes in the number of train-cars. Having a tradeoff between this type of decoupling and deployment aware modelling is an active area of research.

I. Real-time Data Driven Monitoring and Optimization Method for loT -based Sensible Production Process [8]

The productivity of the manufacturing process is hampered by the lack of timely and accurate information about the dynamic changes happening on the floor of the assembly line. Advances in IoT and Ubiquitous Computing has given the capability to embed sensors inside the different components used in manufacturing, and enable real-time sensing and actuation based on the data. This improves productivity, cuts costs, improves the efficiency of the process, cuts the logistics cost, etc.

This paper discusses a conceptual Wireless Manufacturing (WM) using the data collected by all the RFID tags throughout the supply chain. This data is then used to make decisions dynamically, in real-time. This type of a system has already been developed for a Grocery chain, by a Spanish company Ecomovistand.

Some of the challenges faced in using IoT in manufacturing systems are:

1. Development of a comprehensive IoT architecture for the entire supply chain.

2. Interpreting and analysing the vast amount of distributed data being supplied from different components in the manufacturing system.

3. Enforcing real-time optimization routines in certain parts of the supply-chain, based on real-time data?

This paper attempts to solve these challenges, with a special focus on the optimization strategies.

This paper makes four important contributions in achieving this aim:

1. Development of the architecture for the IoT manufacturing process. An integral part of this architecture is to embed the RFID/Auto-ID tags into certain key components.

2. Enable sensors in the manufacturing side, so that the manufacturers can produce items in a smart way - this includes enabling communication between devices and encoding certain logic for the production systems.

3. The third contribution is in analysing the data obtained from the distributed sensors present in many components. This methodology helps obtain useful and interpretable information, from the raw data.

4. The fourth contribution is in the dynamic optimization of the manufacturing process, by making use of real-time data.

J. IoT Based Smart Rehabilitation System [9]

IoT has enabled the interconnection of many devices through the internet. IoT becomes especially useful in cases of an aging population and an acute shortage of healthcare professionals. Although it IoT has been experimented with in this area, some challenges prove to be obstacles from achieving rapid answers to a patient's symptoms and needs. This paper proposes to address this through Ontology-based Automatic Design Methodology(ADM).

The average age of the population tends towards to be over 50 for many of the countries. The rehabilitation of the elderly is an important concern as it requires the energy, resources and manpower of the society. Community facilitation for rehabilitation aims to provide better interaction, adequate resources and timely solutions to every patient's individual needs tailored to every patient's individual requirements, better than the services offered by a hospital. This idea is achieved through the IoT devices, which provide the important ability of interaction between many sensors and actuators.

The usage of IoT can indeed bring in a huge amount of information from the numerous sensors used, and increases the complexity of the system by a large amount. Also, the data in itself is not sufficient in solving the intended problems. Hence two key challenges exist in this scenario:

1. Quick diagnosis of the patient (by identifying the symptoms)

2. Enforcing a quick rehabilitation strategy and identifying/procuring the medical resour ces based on the diagnosis.

This paper aims to construct an architecture/design system for efficient sharing of information across all devices. The success of preliminary tests indicate that larger, real-world tests need to be conducted in order to test the efficacy of this system.

K. IoT-Cloud Service Optimization in Next Generation Smart Environments [10]

IoT technology can only reach its potential if we can optimise the combined usage of IoT and Cloud services. Today, the workflow of most of the services involve sending all of the data from sensors/devices to a centralised cloud, where processing of the data is performed. But this obviously brings in disadvantages like increased latency, higher power consumption, huge network load, etc. But advances in network virtualization, distributed cloud-network architectures are being improved upon to solve this problem. In this paper, this problem is mathematically modelled as the minimum-cost mixed cast problem, and it is shown to be efficiently solved using linear programming.

In order to maintain the stringent Quality of Service (QoS) requirements, distributed cloud architectures are being increasingly used. Some examples are cloudlets, micro-clouds, fog-clouds, etc where each of these components are present at the edge of the network and have varying degrees of compute, storage and other resources. Today, even some of the end IoT devices are being used to provide varying degrees of these capabilities, by exploiting high degree of virtualization layers in the device. This has helped in decreasing latencies and other related problems. This type of interconnection of cloud and IoT devices has been referred to as Cloud-IoT network.

In these types of virtualized environments, all the services use the virtual-slices of resources, as per the demand. So a critical component of such a system is in efficient routing of the resource-requests sticking to the constraints and simultaneously maintaining the efficiency.

III. Discussions and Findings

A summary of the findings of all the considered research papers has been presented below. It is interesting to note that many of the approaches are trying to solve these optimization problems using the well-known and studied graph algorithms, mixed-cast minimum cost models, etc. Also, many of these works imply that the success of IoT technology critically depends on advances in other allied fields like Computer Networks, Distributed Systems, Privacy and Security, etc.

TABLE I.

Sl. No.	**Summary of all the papers**		
	Research Paper Title	***Author***	***Findings***
1.	Graph based M2M optimization in an IoT environment	Paul Anand	Modelling the nodes in IoT as a graph
2.	CCN Traffic Optimization for IoT	François, Jérôme et al	Usage of Content Centric Networking for communication in IoT
3.	Internet of Things (IoT): A vision, architectural elements, and future directions	Gubbi, Jayavardhana, et al.	Comprehensive overview of the evolution of IoT technology
4.	A Framework for Building a Collaborative Environment in an Open IoT Platform	Lee, Wonho, and Jae Wan Park	Platform for systematically storing and recording ideas, development and data
5.	A Study of Internet of Things (IoT) Applications	Kang, Y., et al	A study on the current use-cases of IoT technology
6.	Ravel: Programming IoT Applications as Distributed Models, Views, and Controllers	Riliskis, Laurynas, James Hong, and Philip Levis	MVC architecture for programming multiple tiers in IoT Application

7.	Virtual Storage System based on Multiple Embedded Devices in IoT Environments	Lee, Hwi-Ho, et al.	Virtual storage system based on the multiple embedded devices in IoT environments
8.	Living in the Cloud or on the Edge: Opportunities and Challenges of IOT Application Architecture	Tata, Samir, et al	Addresses challenges in Modelling and Deployment of IoT Applications
9.	Real-time Data Driven Monitoring and Optimization Method for loT -based Sensible Production Process	Zhang, Yingfeng, and Shudong Sun	Application of IoT for semi-automatic decision-making in Manufacturing Supply Chain
10.	IoT-based smart rehabilitation system	Fan, Yuan Jie, et al	Usage of Automatic Design Methodology in modelling IoT applications
11.	IoT-cloud service optimization in next generation smart environments.	Barcelo, Marc, et al	Optimization of network flow in IoT-Cloud Network

Conclusion

IoT is one of the rapidly growing technology of the 21st Century. While it has grown by leaps and bounds, since its inception in the 1960s, there is a lot of potential for research in novel areas like IoT-Cloud Networks, Virtual storage space on embedded devices, etc. The progress in these areas are of quintessential importance for the overall growth of IoT today.

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