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Edge, Fog and Cloud-based Smart Communications for IoT Network based Services & Applications

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***Abstract*—The Internet of Things is increasing its span in our daily life, intelligent homes, agriculture, industries and smart cities are few popular fields among application areas. Use of smart devices connected over the network can be seen in the mentioned fields. Vast data is collected through the connected devices using wireless sensors and then transmitted over the network to the edge and cloud for the computation. The increase in sensory devices lead to more data generation thereby there is also raise in wireless terminals as now more data is generated. This brings some challenges that need to be resolved, like processing delay leading to more time consumption, data bandwidth issues affecting data transfer rate and computation capability. It has been identified that massive work needs to be researched on communication medium to provide IoT services among the applications. Various frameworks like TelcoFog, Edge framework, CoSMOS, ROUTER, FogFlow, Deep Learning and IoTecture were studied and their results were analysed. This paper aims to understand the role of different communication channels for edge/fog and cloud-based computing, and understand their role in different computation methodologies.**

Keywords—Internet of Things, cloud/edge computing, 5G, communication channels

I. INTRODUCTION

The involvement of Internet of Things (IoT) is rapidly increasing in day to day applications like smart homes, agriculture, transport and industries which are used to provide the routine services to the users. IoT applications demand a highly scalable environment due to the growth-oriented architecture, which raises several challenges in the development and deployment of IoT applications and services. These requirements raise another issue due to massive data generation over many sensors deployed over the physical devices. Such massive data generation raises the need for high computation and demands the faster wireless terminals and communication channels [1]. Different communication channels are available and used by many authors to implement their proposed frameworks and models to provide IoT applications and services. 5G networks, Mobile Edge Computing (MEC) are few of the proven and promising technologies among the solutions to many wireless terminals. It works by making computing and caching near to edge of the network [2].

With the rapid development and evolution in IoT applications, involved use case scenarios, computing is reaching and becoming part of all the activities of the daily life. Such evolvement is creating a significant shift from application development to deployment. With influence increasing exponentially, an intelligent methodology for deploying these applications is critical for achieving effective utilization of the network infrastructure. For affective deployment of IoT application modules in fog-cloud architecture, there is requirement of efficient utilization of the network infrastructure by the applications. Main types of network structures are available that act as a medium of communication among physical devices and the cloud. Fog computing brings the IoT applications closer to the source devices and users. Here the computation is dynamically distributed across the fog and cloud layer [3]. A new paradigm termed computation or data offloading to solve critical issues like latency and energy consumption between the IoT applications has been proposed by many researchers. The focus is to implement different offloading approaches to make offloading an adaptive approach with the change in an environment by using a smart gateway. For data and computation offloading, researchers are actively working to identify offloading schemes with the changing environment [4]. Under the key requirement to achieve fast response and efficient data storage with minimum energy consumption [5] for IoT applications and services different communication or network schemes are used. Fig. 1. Schematically shows the standard edge/cloud communication scenario where different network channels can be used as a median of communication.

In Figure 1. edges show the devices generating large amount of the sensor data that is of raw form, for extracting and processing information out of them they need to be processed over the micro-data centers / cloudlets forming the fog architecture. Sometimes according to the resource requirement or the fog capacity data required to be processed over the cloud, under such scenario channel or medium to transfer data may play a vital role and considered as an objective under current research to achieve efficient services among IoT applications.

The purpose of the development of fog computing scheme was to serve as intermediate in between IoT and cloud, and thus making a hierarchy for processing and computing, by bringing it near to the edge devices itself and improve the performance parameters. There is a possibility of reduction of data transfer and communication time by uniting fog and cloud structures and can also aid in reducing latencies, as fog computing resources exist closer to the edge devices [6]. In next section we have discussed the literature where many papers have proposed smart communication methodologies by implementing a smart gateway in between.

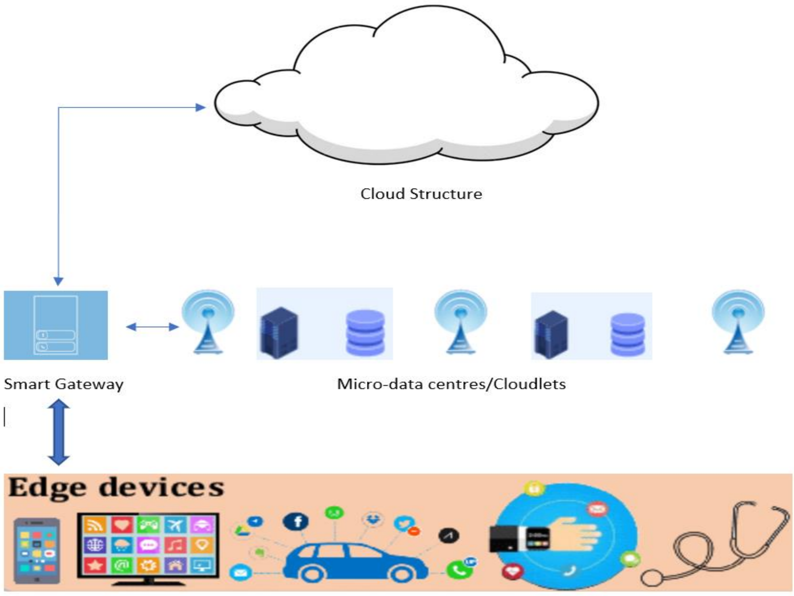

Fig. 1. General Edge/Cloud communication scenario

II. Literature Survey

In this section we will discuss the several proposed frameworks and models for the smart communication among the edge/fog-based cloud structures, their role and working for providing the IoT services to the end users.

To provide service usage for external applications like smart city, industry or IoT a TecoFog [7] architecture is proposed by Vilalta et. al, here a novel, secure, distributed fog computing architecture is given. Services are given at the edges of wire or wireless network having telecom operators, with the purpose of bringing manifold unified, cost-beneficial and new 5G services, like Network Function Virtualization (NFV), Mobile Edge Computing (MEC). Authors in [8] proposed a Heating, Ventilation and AC (HVAC) service developed using YANG modelling language, built up for IoT services and their description. The model basics for joining the NFV and MEC services, letting telecom workers to lessen their Total Cost of Ownership (TCO) [8].

Study show that as huge amount of data is generated at the end points, processing this data at edges can improve the performance of whole system [9], on such theory Hossain et. al [10] presented an edge computing approach, besides processing all the data at the cloud which is costly methodology in terms of processing time, latency and storage. Here the computations are brought near to the devices where data is produced to minimize such challenges, a fixed window size approach is used where node samples the sensor stream data.

For offloading data and computations context-based structures are gaining importance, in this stream a Context-Sensitive Model for Offloading System (CoSMOS) is presented in [11], here authors proposed a situation sensitive, self-adaptive decision support offloading model for mobile cloud computing systems. A Mobile Cloud Computing (MCC) based existing MpOS [12] model is used for the implementation as its foundation. To decide accurately for making the decision about offloading of applications components, the offloading choice is made on estimation of implementation time and consumption of energy for the applications to improve systems execution. Authors in [5] proposed Dynamic Energy Efficient Data offloading (DEED) scheduling algorithm, it display an unstable channel state in network communication model. Three models task reliability, energy consumption and device reliability are given with the sole purpose of optimizing energy consumption.

A fog powered cloud computation-based framework is given by Singh Gill et al. [13], founded on the idea of managing of resources for smart homes. The presented method is named as ResOUrce managemenT tEchnique for smaRt homes (ROUTER), the whole thing works on the various parameters like the total time taken to respond, bandwidth consumed over the network, consumption of energy and latency in parallel by making use of Particle Swarm Optimization algorithm (PSO) to enhance the performance of these parameters. Authors in [14] presented a a computing framework based on fog architecture termed as FogFlow for IoT smart city platforms. FogFlow’s framework shows programming model that lets developers to program over the cloud and edges for scalable IoT services. A standard approach is used and next generation service interface (NGSI) based on contextual data transfer is given.

Integration of MEC with the 5G ecosystems and role of Small Base Stations (SBS) and challenges are discussed in [15], Zhao et. al [16] taken this study further and realised the need of accurate prediction for making the decision of offloading data. In this framework to determine the offloading scenario that whether it ought to be achieved on Small Base Stations (SBS), a multi-LSTM grounded estimation model is created. Based upon the estimation, worth and priority of the end user, Cross Entropy (CE) methodology based offloading algorithm is projected to enhance the system performance. In [17] authors proposed IoTecture a 5-layer based architecture for IoT and IoTinuum a 5-stage Computing Continuum for IoT, taking six configurations a performance analysis is done. A Low Power Wide Area Network (LPWAN) technology LoRaWAN is used for the deployment and the implementation.

III. Comparative Study

TecoFog [7] uses the 5G services for the network building, HVAC service is presented in the model for IoT services description. It allows telecom operators to reduce their Total Cost of Ownership. In [9] Edge Computing approach is presented; here multi-interface cellular base stations are used to transfer the data with fixed window size approach. The presented CoSMOS [11] model presents a context based scheme where adaptive offloading is performed by the model for mobile cloud. WiFi & 3G offloading communication support used for the experimentation purpose. ROUTER [13] uses the 3G/4G and WiFi to create the field area network, it gathers data by bottommost layer (IoT) and creates communication among edge devices and the cloud datacentre. FogFlow [14] a fog computing-based framework, having IoT services for cloud and edges for serving smart city platforms. It uses MQTT protocol as a mediation operator. A deep learning based a multi-Long Short Term Memory (LSTM) approach is presented in [16] where WiFi AP is used to offload devices from small base stations (SBS). In [17] Wi-Fi WLAN and 4G connection are used for connectivity. The low power wide area network (LPWAN) such as LoRaWAN is used to implement FIWARE-based IoT platform.

For TecoFog in Figure 2. we had considered only total orchestration delay, in edge case scenario we had taken approximate average of three scenarios discussed in paper 0.102 seconds (sec) in offline mode for CityPulse data set, 0.4 seconds for the Chicago park data set and approximately 4.35 seconds in real-time scenario. On the same guideline the maximum average execution time is calculated for CoSMOS but in two scenarios, where 0.914 seconds over Cloudlet WiFi, 1.067 seconds over the Cloud WiFi and 5.024 seconds over Cloud 3G is not considered as the time increases in 3G communication model. One important point to see in this framework is that Cloudlet WiFi is the most successful model in CoSMOS. ROUTER has average response time and latency of 6.768 seconds. Average response time of the FogFlow- Discovery is taken as it is divided into three categories of 0.508 milliseconds (ms) in ID-based, 0.614 ms in topic-based and 1.850 ms in geoscope-based. IoTecture IoTinuum framework shows two situations of smart agriculture and city where 212 ms, 249 ms and 410 ms over 500,1000 and 1500 messages per minute for smart agriculture. 199 ms, 219 ms and 597 ms over 480, 960 and 1440 messages per minute of smart city.

Figure 3. displays the maximum approximate average energy consumption of CoSMOS and ROUTER frameworks.

Energy consumption of other frameworks which are part of literature are not available, the Figure 3. Clearly shows the advantage of using the WiFi network channel.

Figure 4. presents the overall throughput for the available models, this compares the performance of these computing frameworks.

The mentioned SBS is implemented over the WiFi network channel, thus by comparing we can conclude that WiFi frameworks implementation has better performance.

TABLE I
Comparison of Different Frameworks

Frameworks/Models	Average Throughput (Mbps)	Average Energy Consumption (Joules)	Average Execution Time (Milliseconds)
FogFlow-Discovery (ID-based)	20	NA	0.9908
FogFlow-Discovery(topic-based)	15.62	NA	NA
Deep Learning Model (single-SBS)	1.24	NA	NA
Deep Learning Model (multi-SBS)	467.5	NA	NA
CoSMOS (Cloudlet WiFi)	NA	0.452	NA
CoSMOS (Cloud WiFi)	NA	0.371	1971
CoSMOS (Cloud 3G)	NA	1.574	NA
ROUTER	NA	3.3389	6768
(TecloFog) Total Orchestration delay	NA	NA	20350
Edge Computing Structure	NA	NA	1617
IoTecture IoTinuum (Smart Agriculture)	NA	NA	291
IoTecture IoTinuum (Smart City)	NA	NA	339

TABLE I presents the different frameworks and models with their approximate average throughput, energy consumption and execution time in different communication scenarios. Here NA means data is not part of respective authors research and experimental work.

IV. Future Directions & Challeneges

From the literature review and results it has been identified, that their exists some limitations with the existing work and there is scope of study in future. Mentioned points lists the identified challenges and scope of future work in them.

- In future there is possibility of work by developing algorithms that can be learning based or hybrid to supports mobility-aware optimization for edge computing. Fault tolerance algorithms can be added with the algorithms as during communication of data many faulty situations arises.
- Computation offloading to process the information on cloud or edges is new and bright scenario to achieve accurate IoT services with key performance parameters like latency, time and energy consumption. In future more, work can be done on

offloading strategies possibly with some hybrid algorithms to further improve them.

- As there are various advantages, there is also chances of degradation of performance due to the implementation of computation offloading techniques. This can be due to unbalanced changing environment and varying usages of applications as it kept growing with the time. Therefore, in the direction of making improvement to optimize application execution environment, self-supportive and context adaptive and sensitive capabilities are needed.
- The integration of IoT services with the cloud and fog structures is already challenging and issue further rises with the deployment of 5G, as it is not fully successful. With such integration more, issues also raised in terms of resource managements as IoT applications are highly scalable and heterogeneous modules keeps on adding.
- There is requirement of more research and experimentation work to more properly understand the role of different communications channels, to study this same model can be tested on different networks channels.

V. CONCLUSION

To provide the IoT services role of different network architectures are studied, from the analysis of results it has been identified that communication channels is mostly ignored and there is more focus on methodology on performing the computations.

Although very less work has been done on communication channels, but from the analysed results it can be figured out that WiFi and 5G services have more importance and can be preferred over the 3G like network scenarios.
It also has been identified that it's true to say that to perform the computations for achieving the optimum response in terms of time consumption, energy and overall throughput in edge/cloud-based structures the computation and offloading methodologies has more impact.

Although a little impact by the communication channel is due to common protocols used by the communication channels like MQTT, their role can't be ignored. The communications channels do improve the implementation and execution process for the applications, but also occasionally they can lead to reduce its performance due to rapidly changing environment termed as unstable environment and due to scalability changing application usages.

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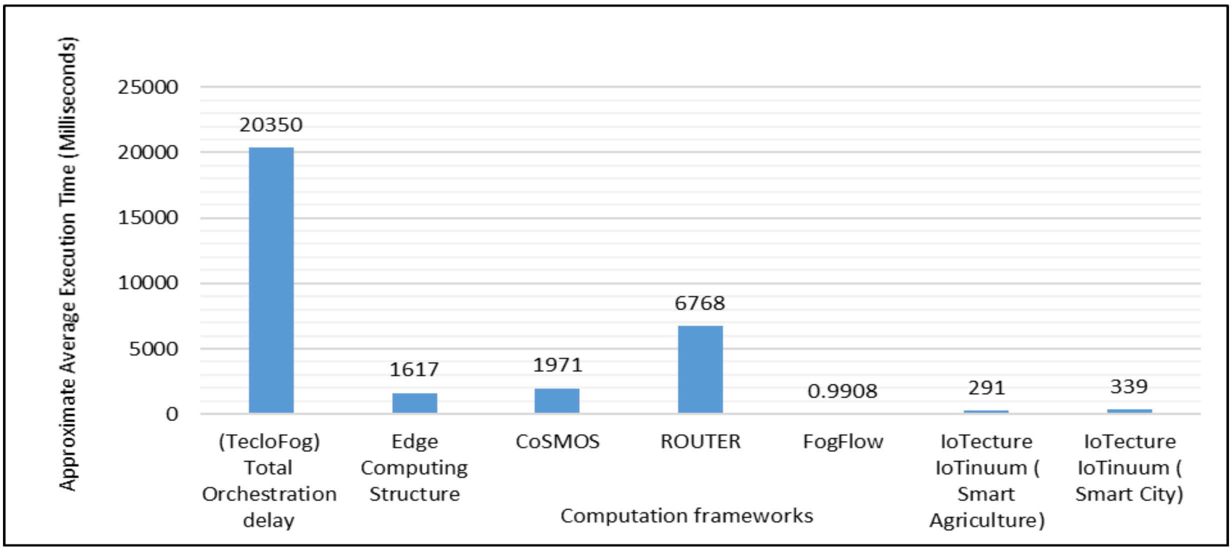

Fig. 2. Experiment results of different implemented frameworks

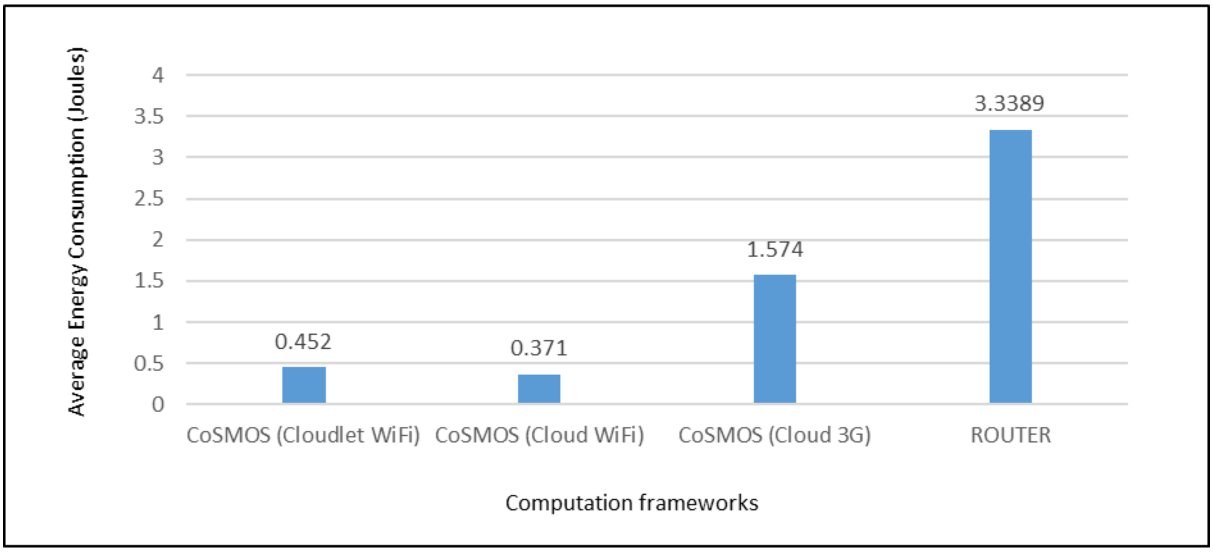

Fig. 3. Approximate average energy consumption of frameworks

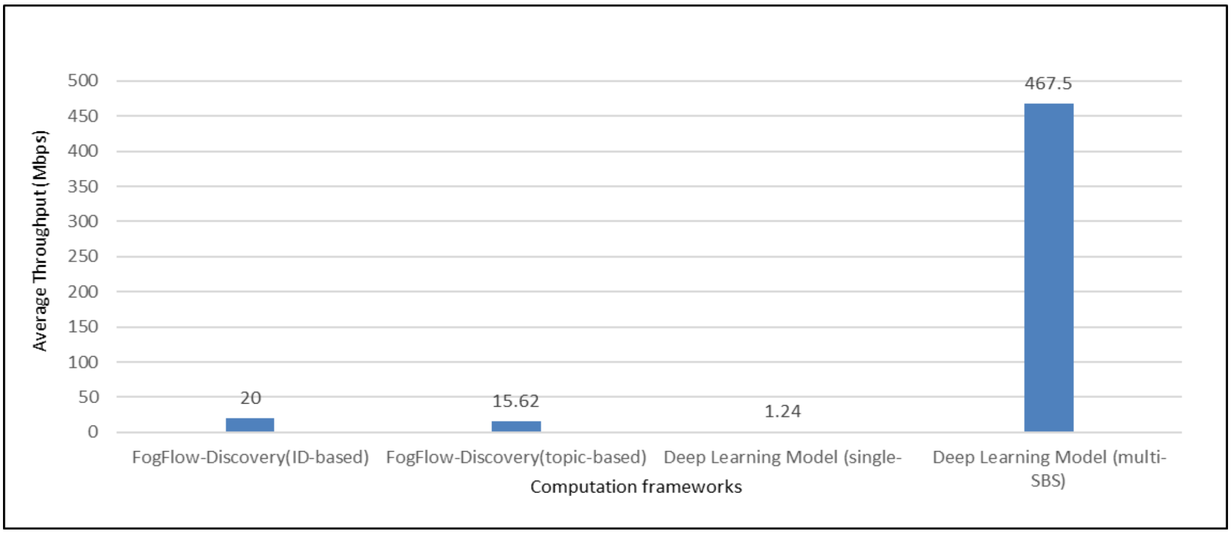

Fig. 4. Overall average throughput for frameworks