Mobile Edge Cloud computing with Big Data Analytics in IoT Networks

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Abstract : **We are witnessing the emergence of new big data processing architectures due to the convergence of the Internet of Things (IoTs), edge computing and cloud computing. Existing big data processing architectures are underpinned by the transfer of raw data streams to the cloud computing environment for processing and analysis.Among these areas, IoT is considered as an important platform in bringing people, processes, data and things/objects together in order to enhance the quality of our everyday lives. However, the key challenges are how to effectively extract useful features from the massive amount of heterogeneous data generated by resource-constrained IoT devices in order to provide real-time information and feedback to the end-users, and how to utilize this data-aware intelligence in enhancing the performance of wireless IoT networks. The proposed framework can exploit the network wide knowledge and historical information available at the cloud centre to guide edge computing units towards satisfying various performance requirements of heterogeneous wireless IoT networks. Starting with the main features of big data analytics, we provide various synergies and distinctions between cloud and edge processing. This research also shows that data reduction inside mobile edgedevices lowers the communication and computational burden in existing IoT-cloud communicationmodels.**

IndexTerms: **Big data, Data analytics, Internet of things (IoT), Cloud computing, Edge computing, Mobile edge cloud computing (MECC) -**

I. INTRODUCTION

Cloud computing systems provide highly virtualized computing, networking, and storage services on top of massively parallel distributed systems. However, clouds were initially introduced as utility computing models to fulfil the processing requirements of enterprise applications [1]. The voluminous and high speed data streams in IoT-based big data systems increase the network traffic of the cloud, which challenges the big data management capabilities [4]. Data storage and computation are two critical problems in cloud computing, which provides a method to solve thelimited storage and computing speed of computers or mobilephones [1].With the development of Internet of Things (IoT),the amount of data transmission shows a trend of exponentialincrement [2, 3]. It is predicted that the growth trend of datatraffic would be eightfold between 2014 and 2020, which willbring a huge challenge for cloud computing [5]. On onehand, limited bandwidth has adverse effects on the efficiencyof data transmission. On the other hand, terminal is usuallyfar from the cloud servers and data transmission with longdistance increases the transmission delay, which does notmeet the requirement of real time, low latency, and high quality of service (QoS) in the network of thousands of IoTdevices and affects the overall efficiency of the system [6, 7].Due to the fact that traditional cloud computing posesmany challenges, mobile edge computing (MEC) is proposed,which consists of relatively weak edge devices [8–10]. MEC isa novel paradigm that extends cloud computing capabilitiesand services to the edge of the network.

On one hand, MECensures that data processing mainly depends on the localdevices rather than the cloud servers. On the other hand,MEC usually does not need to establish a relationship withremote cloud servers; it can meet most requirements of localusers very well [7].On the other hand, the concept of edge computing, also called fog computing1, is receiving important attention in order to address some of the drawbacks of cloud computing [8]. The main goal of edge computing is to extend the cloud computing functions to the edges of the network. Due to proximity to the end-users and geographically distributed deployment, it can support the applications/services demanding the requirements of low-latency, location-awareness, high mobility and high QoS [9]. However, edge computing units usually do not have enough storage and computing resources in handing the massive amount of IoT data. In addition, due to several involved constraints such as low-power, heterogeneity and weak capability of devices, IoT environment is more vulnerable to the information security. Therefore, there is a clear need to investigate suitable network architecture and control mechanisms to handle the processing of massive IoT data in a secured manner.

II. BIG DATA ANALYTICS IN IOT

Features of big data:

The term “Big data” usually refers to extremely large, heterogeneous and complex (semi-structured and unstructured) data-sets, which cannot be handled by the conventional data processing and storage tools/applications such as Relational Database Management System (RDBMS). The importance of big data lies on how meaningful information can be extracted from it for a particular application rather than the size of the data, and this extraction process requires novel data analysis methods and huge processing power. In wireless IoT environments, big data may be generated from a variety of application scenarios ranging from smart home scenario to e-Healthcare applications. In addition to the importance of content and control signalling data in wireless networks, location-based data from various sensors such as GPS sensors and embedded sensors in mobile devices can provide significant inputs to the government bodies in developing specific strategies for public facilities, transportation system, emergency responses and crime/risk warnings. Moreover, by analysing the habits and interests of customers, industries may plan their future products in order to address their customers' personalized as well as group needs [10].

The commonly discussed attributes of big data are: (i) volume, (ii) variety, (iii) veracity, (iv) velocity, and (v) value. The first two attributes, i.e., volume and variety, reflect to the hardware and software requirements in handling massive heterogeneous data-sets while the variety and velocity translate into the real-time processing ability with sufficient trustworthiness. On the other hand, acquisition of the highest useful value from the complex big data-sets in wireless IoT networks requires interdisciplinary cooperation among academia, enterprises and wireless industries.

Benefits of data analytics in IoT applications

1. Smart Transportation
   (a) Reduce the number of accidents by looking into the history of the mishaps
   (b) Minimize traffic congestion
   (c) Optimize shipment movements
   (d) Ensure road safety
2. Smart Healthcare
   (a) Predict epidemics, cures, and disease
   (b) Help insurance companies make better policies
   (c) Pick up the warning signs of any serious illnesses during their early stages
3. Smart Grid
   (a) Help design an optimal pricing plan according to the current power consumption
   (b) Predict future supply needs
   (c) Ensure an appropriate level of electricity supply
4. Smart Inventory System
   (a) Detect fraudulent cases
   (b) Strategically place an advertisement
   (c) Understand customer needs
   (d) Identify potential risks

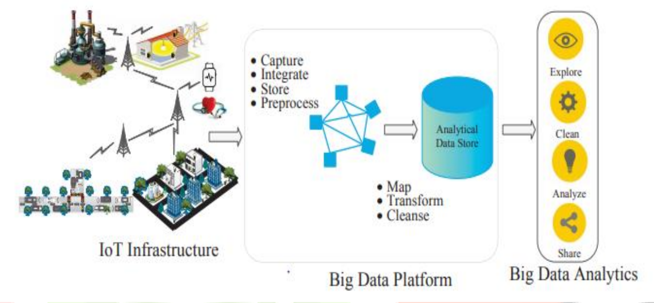

Figure 2.1: Big data analytics with IOT

Figure 2.1illustrates the process of data collection, monitoring, and data analytics. Although IoT has created unprecedented opportunities that can help increase revenue, reduce costs, and ameliorate efficiencies, collecting a huge amount of data alone is insufficient. To generate benefits from IoT, enterprises manage, and analyze a massive volume of sensor data in a scalable and cost-effective manner . In this context, leveraging a big data platform that can assist in consuming and reading diverse data sources as well as in accelerating the data integration process becomes vital. Data integration and analytics allow organizations to revolutionize their business process. Specifically, these enterprises can use data analytics tools to transform a huge volume of sensor collected data into valuable insights. Given the overlapping research trends in these areas, this paper focuses on the recent advances in management of big data and analytics in the IoT paradigm.

III.EDGE COMPUTING VERSUS CLOUD COMPUTING

The key difference between edge and cloud computing is given in below table 1.

TABLE I

KEY DIFFERENCES BETWEEN EDGE COMPUTING AND CLOUD COMPUTING

Features	Cloud computing	Edge computing
Computational capacity	High	Medium to low
Size and Operating mode	Server very large in size and centralized	Edge servers smaller in size and placed over many locations
Applications	Suitable for delay-tolerant and computationally-intensive applications	Suitable for applications demanding low latency, real-time operation and high QoS
Fronthaul/backhaul communication overhead	High since devices need to be connected to Internet throughout entire duration	Low since devices can get cached contents directly from edge gateway
Deployment	Requires complicated deployment planning	Possibility of ad-hoc deployment with no or minimal planning

VI. COLLABORATIVE EDGE-CLOUD COMPUTING

Edge computing and cloud computing solutions have their own distinct advantages and disadvantages from the perspective of live data analytics in wireless IoT networks. The integration of centralized feature of the cloud and the real-time advantage of edge computing can address various issues in dealing with real-time data analytics in wireless IoT networks. Motivated by this aspect, in this section, we propose a novel framework for collaborative edge cloud processing in wireless IoT networks.

Figure 4.1 presents a generalized system model for collaborative edge-cloud processing in heterogeneous wireless IoT networks. In the proposed model, IoT edge gateways are equipped with cache memory and are capable of performing edge-caching in order to deliver the popular contents locally. The edge computing nodes may be any devices having the capability of computing, storage and network connectivity such as routers, switches, and video surveillance cameras. Depending on the application scenarios, IoT networks may comprise of various networks having distinct characteristics. For example, in the smart home scenario, wireless IoT networks may consist of a WiFi network, a blue-tooth network, a Zigbee network and a cellular network. The raw-data coming from different domains/sensors is largely diverse and need to be collected over time. In addition, data dimensions and sizes may be different depending on the considered IoT application scenario. Besides the real-time processing of massive IoT data, this collaborative framework an enable new wireless IoT applications which may require collaborations among different edge computing units, and between edge computing units and the cloud centre. The proposed system will benefit from the advantages of both the cloud computing and edge computing. In addition to this, we envision cloud centre as a monitoring and guidance platform to have effective real-time data processing at the edge-side of wireless IoT networks. In practical scenarios, IoT devices/sensors are heterogeneous in nature in terms of their computing capabilities, intelligence as well as the computing/processing power. In this regard, it becomes highlybeneficial to guide the operation/processing of edge-nodes in order to utilize the available communication and computing resources in an effective manner. In the considered framework, edge computing helps to gather information from the surrounding radio environment while the cloud computing assists by providing suitable instructions to the edge-side nodes for their operations. For example, the operations at the edge-side such as data compression, filtering, sampling rate, power control, and making decisions on the type of data to be sensed/acquired can be supported by the cloud centre by providing suitable control signals over the feedback links.

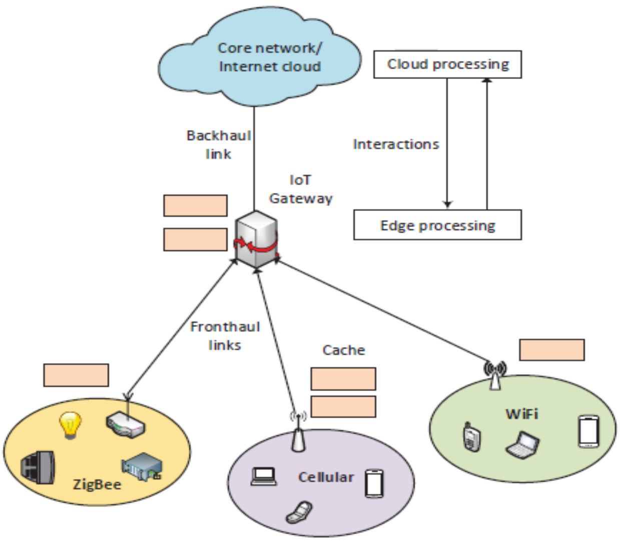

Figure 4.1: Proposed generalized system model for collaborative edge-cloud processing in heterogeneous IoT networks

V. MOBILE EDGE CLOUD COMPUTING

Considering IoT-cloud communication models and the big data generated by mobile edge devices and applications, the cloud-centric big data processing results in increased latency and incremental data transfer cost. In addition, it increases the in-network data movement inside the cloud. Recently, mobile edge cloud computing (MECC) shown in figure 5.1 emerged as a solution to enable the extension of centralized cloud services to the edge of the network through edge servers. These edge servers reside at one-hop communication distances from mobile edge devices; hence, they can meet the real-time needs of IoT applications. However, the decision of data processing in different layers across MECC depends on many factors, such as the capability of devices in MECC, the availability of these devices, the application profile (e.g., real time) and the data analytic tasks employled by the application. Hence, moving data processing from the cloud to MECC is not a trivial task.

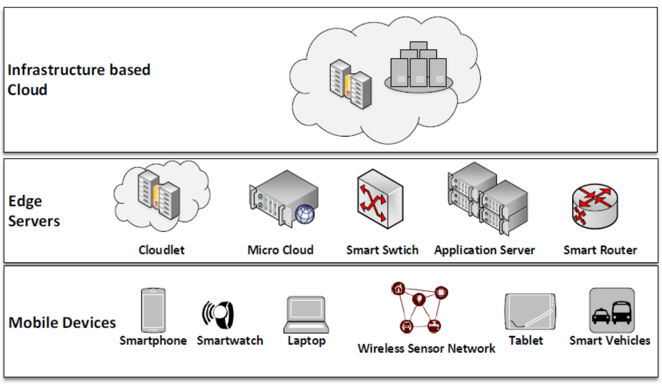

Figure 5.1: The mobile edge cloud computing (MECC) architecture.

VI. RESULTS

Mobile edge devices operate in resource-constrained environments; therefore, power consumption and memory utilization during data reduction were the main considerations during the evaluation.

Figure 6.1shows the power consumption comparison of data uploading strategies. Initially, the raw data streams were uploaded in mobile edge devices, whereby the average battery power consumption for each data chunk remained around 16 mW (milliwatts). However, due to mobility constraints and switching among different networks, sometimes the average power overhead on the mobile edge device increased about 3 mW. The maximum power consumed during raw data uploading in mobile edge devices remained 19 mW. Comparatively during raw data uploading in clouds, the mobile edge device consumed less power, whereby the average consumption remained around 11 mW. However, the RedEdge architecture improves the performance, whereby the cost of uploading knowledge patterns remained around 1.33 mW on average. The experiment revealed that power consumption for knowledge transfer was almost 12-times lower as compared with raw data transfer in mobile edge devices and almost eight-times lower in the case of the comparison with raw data transfer in the cloud.

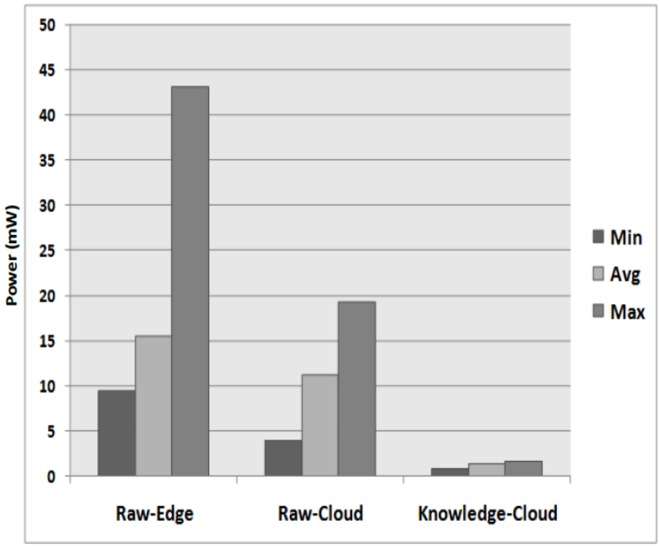

Figure 6.1: Power consumption comparisons.

Figure 6.2shows the memory consumption during raw data uploading and knowledge transfer in mobile edge devices and clouds. The mobile edge devices consumed 29 MB and 27 MB of total memory during raw data transfer in mobile edge devices and clouds, respectively. However, the memory consumption lowered up to 15 MB during knowledge pattern transfer in the cloud.

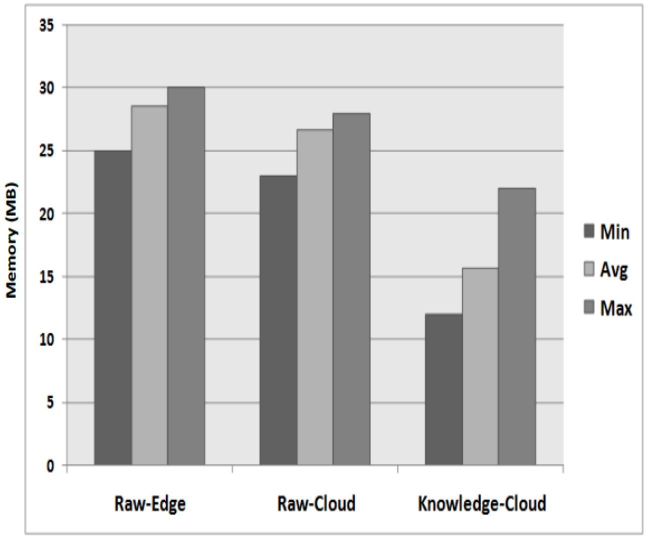

Figure 6.2.: Memory consumption analysis.

VII. CONCLUSION

Cloud computing and edge computing are considered as two emerging paradigms in handling the massive amount of distributed data generated by IoT devices. However, these paradigms have their own advantages and disadvantages. Cloud computing provides a centralized pool of storage and computing resources and has a global view of the network but it is not suitable for applications demanding low latency, real-time operation and high QoS. On the other hand, edge computing is suitable for the applications which need real-time treatment, mobility support, and location/context awareness but does not usually have sufficient computing andstorage resources. Taking these aspects into consideration, this paper has proposed a novel framework of collaborative edge-cloud processing for enabling live data analytics in wireless IoT networks. The basic features, key enablers and the challenges of big data analytics in wireless IoT networks have been described and the main distinctions between cloud and edge processing have been presented. Furthermore, potential key enablers for the proposed collaborative edge-cloud computing framework have been identified and the associated key challenges have been presented in order to foster future research activities in this domain. This research also shows that data reduction inside mobile edge devices lowers the communication and computational burden in existing IoT-cloud communication models.

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