

# Conceptual Analytics on Integration of Network Technologies with Crowdsourcing Infrastructure

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## ABSTRACT

Technology seeks a new dimension as collaboration of various methods and technologies in transmission of data. Crowdsourcing enables the availability of huge data over a variety of networks. It is important to understand the needs of the management and monitoring of such data over a long distance and among a huge population especially among a big crowd like that of temples and other public places. Hence integration of network technologies has to be considered for effective attainment of data transfer with high speed and better performance that includes latency. The paper conducts analytics of various collaborated network technologies that was utilised to handle huge data from a crowdsourced network. The network technologies considered for the reviews are Edge computing, Fog computing, IoT based sensors, mobile technologies and cloud-based platforms. After significant analysis of all the research works, it was identified that edge computing has been the chief network technology used to transmit crowdsourced data with speed and efficiency. Cloud platforms assist the transferred data to be stored with privacy and security. The IoT sensors and Fog computing helped in detecting the data and also to increase the bandwidth and improve latency problems. The research gap identified was to enhance the speed and efficiency of transmission in public related problems like surveillance and handling public or social media database which seemed to be more challenging and encouraging future research works.

**Keywords:** Cloud Platforms-Crowdsourcing, Edge computing, Fog computing, Integration of Network Technologies, IoT sensors.

## 1. INTRODUCTION

Network Technologies are significant in building future requirements of the world as it is capable of bringing in collaboration of different technologies that are capable of satisfying human needs in a city or any region [2-5]. A huge amount of data is available in the world which needs to be integrated to make this world a global village where people and data would be brought close together [6, 31-33]. Crowdsourcing is a technological model which is capable of obtaining information from various sources related to commercial, educative or a particular domain like CCTV [7] or traffic surveillance to analyse and make efficient decision making of situations [8-9]. However, crowdsourcing requires the support of various technologies to act with speed in tough situations [10].

Edge computing is a technology that helps in enhancing the speed of transmission especially that contains huge data like that of crowdsourcing [11-15, 25].

The crowdsourced data were studied by Fernando *et al.* [1] and developed a work sharing algorithm called 'honeybee' to combine three major technologies edge, cloud and crowdsource methods. This model identified the crowdsourced mobile data from cloud and transferred information to remote cloud areas. The major factors considered were node heterogeneity, capability of workers and dynamic abilities to schedule and handle mobile based devices. Also, Yousefpour *et al.* [2] conducted an analysis on various integration of technologies. The edge computing methods and IoT methods were combined for effective analysis of human computer interaction with utilisation of fog

computing as well [35-42]. The analysis suggested methods that these technologies could be combined to bring more privacy and enhanced network communication in all fields. These methods created a hope that integration of technologies was possible in earlier scenarios and have provided good outcomes in terms of latency, speed and performance. Lopez *et al.* [3] envisioned the relationship between human and computers through integration of edge computing as well as human-centred system design techniques. The experiment was successful and contributed to the verdict of possibilities in correlating the different network technologies [57-65].

Many surveys were also conducted based on integration of Edge with Crowd technologies. Bellavista *et al.* [4] developed a novel model called 'Human-Driven Edge Computing (HEC)' to support and enhance the data handling methods in crowdsourcing environment through combining of technologies like edge computing and wireless networks. The research was conducted with a survey of 170 students and conducted a qualitative analysis of efficiency as well as effective nature of edge nodes. Chiang *et al.* [5] identified the relevant works based on combination of fog edged computing with common networking capabilities. The need for integration of technologies were studied and various articles were analysed. The research suggested that integration of technologies would enhance the performance. Prill *et al.* [6] conducted an assessment on collaborating wireless transmissions with crowdsourcing framework. It enabled crowdsourcing data to be handled using PSN network with an enhancement of latency and privacy of communication network. Though it is sufficient to analyse the methods required to integrate crowd and edge technologies, it is also important to analyse and review the performance of integration of such technologies to achieve enhancement in reliability of transmission without anomalies.

## 2. RELATED WORKS

The Review initially combined the study on various methods where edge computing and crowdsourcing technologies were integrated. Few methods are presented to understand the earlier methods where integration was made possible with enhancement in performance as well as reliability features of networks. A Crowdsourcing trust-based evaluation method was developed by Wang *et al.* [7] to combine intelligent mobile edge computing technologies. The method analysed the various nodes of edge based mobile users through computation and management of end nodes. To test the end nodes trustworthy incentive and quality aware trustworthy mechanisms were created and tested with the objective to match their real information with their ability to match their capabilities and cost values. The next objective was to organise tasks and also to

report the results obtained based on trustworthiness of the edge users. The experiment was further validated for testing evaluation of trust as well as incentive-based methods applied to enhance the reliability. The final result identified that proposed hybrid model could enhance the performance of edge users with improved accuracy levels. Huang *et al.* [8] studied the importance of edge computing to be collaborated with crowdsourcing and other network technologies and developed a framework model for learning edge network. The framework had been applied to reduce the traffic in network by avoiding anomalies and congestions during execution time. The method proved to be efficient and adaptable to network Traffic congestions.

Various Architectural models were also proposed for integration of edge and crowdsourcing technologies. A Novel Architectural model was proposed by Grassi *et al.* [9] that was low cost crowdsourced called 'Park Master' which combined machine learning techniques with vision algorithms to find and validate the parking availabilities in cities at any time. The architecture stored combination of image recognition methods as well as video streaming techniques to detect presence of location in parking area using sensors operated through mobile devices like smart phones. This utilised vision algorithms to develop an interface in smart phones to detect the locations of the park. Zhu *et al.* [10] combined the characteristics of edge technologies, crowdsourcing with big data to adapt a best method to transmit huge video data. The best method was chosen after initial analysis of viewer behaviour data. Various methods were used during the research process like auction-based payment schemes for motivated participation of different viewers in the events. A prototype model was developed to demonstrate the reduction of cost as well as stability of services after combining the technologies.

The Edge technology was capable to handle huge dataset created for crowdsourcing as proved by Sun *et al.* [11]. A novel technique was created named 'Simhash' to combine crowd-based edge technology to detect social network information of a friend using thumbs-up data. The 'Movielens' dataset was used to model the results and outcomes suggested that the proposed model was efficient and cost efficient. Various Frameworks where Edge technologies were combined with other network technologies like cloud, IoT and sensors to handle crowdsourced data was also studied. Zhou *et al.* [12] developed a new model called context aware task allocation framework that was capable of sensing mobile crowd in smart city. The network was combined with cloud-based networks layer as well as edge computing layer. The cloud layer was used to handle data like background information, task context as well as feedback of data. The information collected in cloud layer was transferred to

the edge layer and created as part of the total population of data. The edge layer after receiving the information channelized the data and optimised the privacy of information shared.

The preservation of privacy had been the important dimension of study in the research and it determined that edge computing combined with cloud could provide solutions for privacy of data. Kulkarni and Hartmann [15] developed a tool called ‘Turkomatic’ that automatically selects crowd workers and also designs the workflows of each of the employees in real time. The best features were selected from the crowd employers and set as threshold for planning and execution of plan in improving the quality of selection and work. Thus, combination of crowd technologies with cloud platform has encouraged enhancement in quality of outcomes. Schall [14] also developed a quality management tool that were automated using combination of crowdsourcing and edge technologies. The technology concentrated on factors like creating new contents in web, interactive performances, and online collaborations using web 2.0 technologies. The importance was also to remove the barriers and connective nature of technologies. Though Edge and Crowdsourced technologies were combined in earlier methods, it was important to study the integration of different technologies in the same framework and testing was required whether the integration brought adverse or positive consequences or side-effects in the research scenario.

### 3. TAXONOMY AND METHODS

The technologies like cloud computing are useful to store huge amount of data and required support from technologies like Internet of Things, Wireless sensors and of course Edge computing methods to store and process data in an efficient manner. Romana *et al.* [13] identified few problems in cloud computing platform like latency, jitter, context awareness and mobility support to enhance mobile enabled fog computing and edge computing. The major objective of the study was to conduct analytics on the various threats, challenges and inherent methods of edge computing and to develop best methods through collaboration of edge with mobility and other network technologies.

A disaster management framework was developed by Rauniyar *et al.* [16] based on crowdsourcing technology that detects and orders required stages for preventing a disaster. The model was designed to send disaster based IoT data to fog that helps to predict the disasters that might occur in Realtime environment. The designed model was found efficient and safe compared to other traditional cloud based or any disaster models. Thus, combination of crowdsourcing with IoT was possible with these societal requirements. Sharma *et al.* [17] concentrated on fission computing to

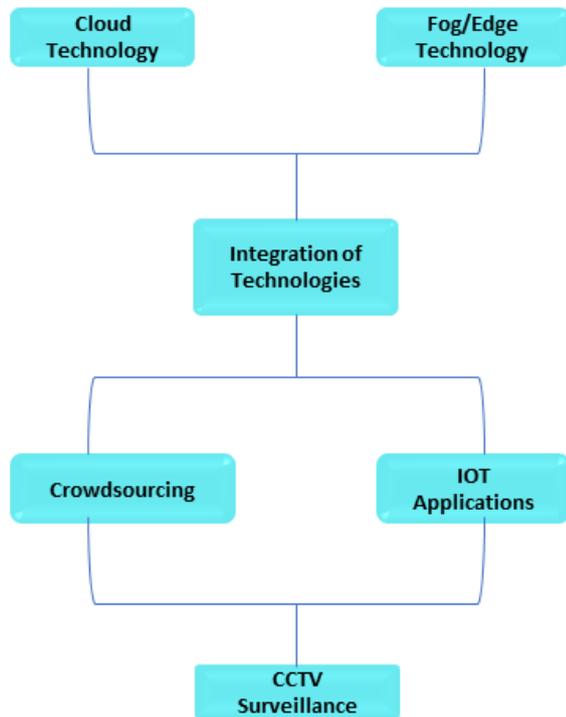
determine the merging of edge computing with crowd resources. The social IoT was considered as the testing component for the fusion and testing was conducted based on two major factors trust and privacy of users. The proposed model utilised crowd-based resources to be used as mini-edge servers and also on entropy-based evaluation. The proposed model had numerical networks models that served as benchmarking component to detect fake sources of s-IoT applications from crowd platforms.

Xu *et al.* [18] analysed the crowd edge-based computing technique to propose a two-level action model for social welfare and security in networks. The initial model proposed the maximisation of social welfare activities by use of factors like incentive compatibility, individual rationality, market clearing and constrained for budget. The second model continued with the proposal of corresponding incentive mechanism that helped to achieve maximum accuracy, efficiency and effective nature of the social mechanism. The Optimal Models also provides significant improvement in improving the anomalies during integration of technologies. Tang *et al.* [19] developed an optimised model for mobile streaming to analyse the traffic signals and to improve the video streaming services. The feat was achieved through collaboration of edge and crowd technologies to enable speedy upload and download of streaming data using mobile technologies. The model used mobile services based on crowdsourcing to identify variations in channels and effective use of resources under networks.

The research also showed future requirements and issues related to the video streaming models. Abdur *et al.* [20] collaborated the mobile and edge technologies to build a framework that was capable to integrate real-time, location-aware services that are privacy based among a big crowd. The technology was developed as hybrid of cloud servers, fog computing based on IoT technologies and 4G/5G networks. The technology worked as the proxy between fog computing terminals and mobile user terminals. Thus, the communication enhancement was possible through network techniques like handshaking, speed of transfer and privacy of the networks. The research had a promising positive effect collaboration of technologies would facilitate data transfer with high speed and privacy.

Another enhanced framework was designed by Xuab *et al.* [21] to integrate technologies like edge computing, cloud and wireless Metropolitan Area Networks to enhance energy aware computation offloading method using edge computing nodes. The study analysed the routes of access points to determine the AP source to destination. The shortest path algorithm designed for the purpose called Non-dominated Sorting Genetic Algorithm II (NSGA-II) for manipulating Multiple Criteria Decision Making

(MCDM) and also for Simple Addictive Weighting (SAW) with optimal solution. The Overall Taxonomy of Integration of Technologies was indicated in Fig.1.



**Figure 1** Taxonomy of Integration of Technologies

The developed model showed best results compared to other models.

### 3.1 Anomalies in Integration of Technologies

The Anomalies are the major source of non-reliable features that becomes a hurdle in integration of technologies. However, it is important to understand the source of anomalies and the methods to improve the performance through various reviews. Yang *et al.* [22] identified the best methods for selecting the workers in spatial crowdsourcing based on mobile and edge technologies. The factors like performance, tasks related to platforms, services were considered for testing the performance. The method allowed users to record their regular information in fog server from which the workers were selected. The proposed method and algorithm were found effective based on theoretical analysis and being tested with real-world dataset. Also, a comparative analysis on multiple client’s behaviour was conducted by Guan *et al.* [23] in edge computing paradigm through applying game theory and model the interaction between users and edge servers. The research utilised the Nash Equilibrium in the game theory to establish dynamic strategy in process that were competing for resources using edge computing nodes of the server.

Various algorithms were designed to handle integration of technologies to handle the anomalies and also to enhance the performance. Xu *et al.* [24] combined the technologies of edge computing, wireless technologies and sensors to develop a time-efficient data offloading method to model and preserve the privacy among users of the customers in networking environment. The model prevented leakages in the edge computing data transfers. The optimised model called Strength Pareto Evolutionary Algorithm (SPEA2) was developed and found with good efficiency and reliability. A cost and energy efficient model were developed by Peng *et al.* [10] [21] that consumed less time of resource utilisation in cloud-based environment as well as mobile edge computing. The study used two models: multi objective computation offloading method as well as non-dominated sorting genetic algorithm II to find optimal offloading strategies as well as workflow dimensions. The proposed method was proved effective by applying it in MEC.

Sapienza *et al.* [27] developed a collaborative model comprised of edge computing and mobile computing to alert the users in base transceiver system that might be closer to critical areas of a smart city. The major area of concern for the research was to test the latency of networks, bandwidth to transfer huge data. It also predicted critical data among the real-time data like that of terrorist attack or any natural disasters. It combined fog computing and mobile edge computing to solve the problems. This model provided insights for security models for the future. Based on the survey it was identified that integration of technologies could prevent the occurrence of anomalies during transmission and increases anomalies and reliability.

### 4. DISCUSSIONS ON EXISTING MODELS

The integration of Crowdsourcing with Edge computing and other network technologies had been previously used to develop many applications in real-time environment and offline frameworks as well. Ananthanarayanan *et al.* [26] conducted an analysis on real-time video to develop an Edge computing Application called ‘Killer App’ that was capable of integrating cloud infrastructure with security cameras and transfer them safe with edge technologies. Various techniques for application of real-time analytics were analysed on crowdsourcing based dash camera video streaming by Zhu *et al.* [28] using fog computing in vehicles like taxi and bus. The initial analysis was to identify the presence of vehicle. Next was to find the video streaming under two channels DSRC and LTE networks. Based on the analysis, the performance of transmission and service was assessed. The research proved that crowdsourcing could be related with edge computing to enhance streaming in vehicles.

Goel *et al.* [43] developed a framework that was capable of protecting the securities, environment as well as perform the operation using integration of different kinds of technologies like Natural Language Processing, Deep Learning and Networks integrated with expert systems developed from machine learning models. Thus, it was proved that integration of technologies can be performed as hybrid by combining networks along with non-network technologies.

Lu *et al.* [44] studied and showed that smart cloud technologies could be formed with the integration of network, cloud and enterprise technologies. It was also concluded that integration of different technologies wouldn't cause problems in the technologies to be created.

Erdiwansyah *et al.* [45] were involved in the invention of better solutions to bring cost-effective energy resources for better technological solutions. The research confirmed that interrelated technologies combination has few challenges when integrated and it could be overwhelmed by selecting the best technologies that are capable of satisfying particular needs and also has better transparency.

Bondarenko *et al.* [46] integrated SMART technologies with Internet of Things to build an education learning system that is capable of improving the relevance and validity of the data being stored and processed in a Smart City. It also ensured that image based can be stored and retrieved with ease in cloud using integrated SMART and IOT technologies.

Integration of Technologies can also be utilized in other disciplines like Marine Industry as identified by Plaza-Hernández *et al.* [47]. They used the Integration of IoT and Information Communication Technologies (ICT) to develop a SMARTSEA project. This project enabled better maintenance of technical functions of the Maritime and Surveying industry systems. Thus, it proved that maritime has also been benefitted by the integration of technologies.

Miraz and Ali [48] integrated blockchain and IoT technologies to enhance the security system of the organization referred to as Blockchain of Things (BCoT) and Distributed Ledger Technology (DLT).

The various other applications created based on the integration of technologies and its purpose of integration were tabulated in Table 1.

**Table 1.** Integration of Network Technologies, Crowdsourcing and its applications.

Ref. No	Author	Year	Collaborated Models	Purpose of integration
[45]	He <i>et al.</i>	2017	Fog & Edge computing Crowd sourcing	To telecast Video streaming with seamless transmission
[46]	Zhu & Huang	2018	Internet of Things Crowdsourcing Edge Computing	Resource sharing of customer grounded services.
[47]	Kong <i>et al.</i>	2018	Crowdsourcing Wireless Sensor Networks	Used to test the crowdsourced bus data among sensor data
[49]	Zhao <i>et al.</i>	2017	Edge computing Crowdsourcing Wireless sensors	Image sensing application to be used in Disaster Management
[50]	Chen <i>et al.</i>	2018	Edge Computing Mobile Technology	Develop IoT based applications
[51]	Zhang <i>et al.</i>	2018	Edge Technologies Wireless Networks social crowdsourcing	Used in analyzing delay sensitive social sensing
[52]	Lyu <i>et al.</i>	2018	Green computing Edge computing Crowdsourcing	Handle low latency and reliability in IoT based services
[53]	Wang <i>et al.</i>	2017	Crowdsourcing Edge computing Wireless sensors	Enhancing speed of transmission in television networks
[54]	Satyanarayanan	2017	Wireless networks Crowd sourcing	Situational awareness based on contextual and sensitive views.
[55]	Khan <i>et al.</i>	2020	Crowd image analysis Crowd monitoring Crowd management	Advances and Trends in Real Time Visual Crowd Analysis
[56]	Badidi <i>et al.</i>	2020	Fog computing Cloud computing Smart Cities	Fog Computing for Smart Cities Big Data Management and Analytics: A Review

The Applications of these models indicated that integration of technologies could be applied in various other fields where the technologies could utilise their characteristics and special nature for the benefit of each other. The integrated applications were reviewed and

was found to have enhanced performance levels as well. Zhu *et al.* [29] combines the features of cloud infrastructure with crowdsourced data to monitor live streaming of video contents that were transcoded among different devices connected in various networks.

The computation models were handled with cloud to handle billings. The created model was known as ‘Cloud-Crowd collaborative system’ to handle transcoding of video with an intention to reduce the cost. A testing method was used to identify efficiency in society, ex-post incentive compatibility as well as rational in individuals. The proposed model achieved 93% high performance with best cost saving measures than other traditional models. Rodrigues *et al.* [30] devised an analysis on D2D protocols and their influence on mobile edge technologies which was compared with traditional models to test for latency and communication among devices. Different configurations were used for each of the devices. Finally, the outcomes indicated decentralised models provided more support and efficiency to transfer multimedia data while other models showed up to 65% of reduced access points. Vesdapunt *et al.* [34] collaborated edge computing with crowdsourcing to introduce strategies that could handle complex social media datasets like that of Facebook. Various techniques including algorithms to enhance the communication was proposed during the study. All the proposed models were applied and had been successful in obtaining best results in terms of less latency, increased speed, less bandwidth and reduction in anomalies.

#### **4.1 Integration of Technologies in CCTV Surveillance**

Omali *et al.* [49] induced the importance of Integration of Technologies in manipulating Realtime imaging of CCTV data to enhance security in surveillance. The distribution of Geo space locations and storing of camera data from multiple locations at the same time was carried out using multiple integration of technologies like cloud, IoT and other Network technologies. Also, another CCTV based surveillance security system was developed recognize the Face images in camera. The image recognition is based on the system RAD Methodology. The work also used novel algorithms like Local Binary Pattern Histogram, Eigenface, and Fisherface algorithms for recognition of face images in CCTV systems. The accuracy of the algorithm achieved 95.92% efficiency in predicting the Staff and IT experts in Philippines Police security systems. This model was also used to find the criminal information based on face recognition system. The CCTV surveillance security was also enhanced through the integration of technologies with new innovations like blockchain technologies as shown by Khan *et al.* [50]. All the Integrations of technologies have enhanced performance of anomalies detections in crowd with the use of CCTV surveillance.

The literature review on all the models suggested few recommendations in the proposed research. The

frameworks created by Grassi *et al.* [51] was a low-cost crowdsourced model called ‘Park Master’ set a benchmark for creating practical models where integration of networking technologies was used for an ordinary problem like that of parking of vehicles. The network technologies integrations were also used in traffic analysis, video streaming, disaster management etc. The performance levels of integrated technologies showed an enhancement in various parameters like latency, bandwidth, speed and accuracy of transmission. The methods used in all the technologies suggested that every technology utilised the nature of its own in attainment of successful integration. For example, if a surveillance is to be detected for privacy and security, the crowdsourcing provides the huge data in the form of video recorded every day for a period of time. The Edge computing enhances the speed of transmission using network protocols whereas cloud computing infrastructure would enhance storage facilities of the system. The Internet of things would be sufficient to automate the detection of anomalies through physical integration of all devices and brings solution to complex data in a smart city.

#### **4.2 Research Gaps in the Study**

Though there exist various recompenses in integration of technologies, some of the pitfalls are also observed during the study. The cost of integration of all the technologies was the major concern of integration of technologies especially edge and crowd-based paradigms. The problem also existed in areas where building an infrastructure was very complex and require different tools for implementing and developing a prototype. Crowdsourcing require techniques and algorithms in more enhanced form. Though all the techniques were in theoretical form, the practical implementation has to be possible in the future.

### **5. CONCLUSION**

The research paper analysed and studied various techniques and frameworks that had integration of various network technologies like edge computing, cloud computing, Internet of things and wireless sensor networks with crowdsourcing technologies. The impact of integration of all these technologies with each other has also increased the performance as well. The review has also enriched the development of a novel model that could bring network technologies together to handle huge data and also to handle complex data in the future.

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