# Mobility of Internet of Things and Fog Computing: Concerns and Future Directions

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***Abstract*:** IoT devised the modern world of technology into a world where different objects are joining the global network, exchanging, storing and processing the data using different surrounding environments and actively intercede. Enormous number of services can be visualized and put into reality by using the basic concepts of IoT. Since IoT devices are resource constrained, the concept of edge computing also termed as fog computing was proposed to assist IoT devices in handling and delivery information. The centralized cloud is not replaced by fog but enhances its functionality, accessibility and reliability in many means by distributing its principles and technologies through the CoT continuation, specifically at edge of network. The nearness of the fog and IoT nodes enables many distinctive features that should be available and protected always even during the movement of IoT devices through different places. This article discusses the main challenges by analyzing the concept of providing mobility support in a fog environment.

***Keywords*:** IoT, Fog Computing, 5G, Mobility, Security.

## 1. Introduction

The concept of IoT has revolutionized the modern world of data and communication ideology. It has turned the whole world into a large complex web of modern devices (that includes computer, phones, refrigerators, lamp post, etc) where all devices can join the interne. These devices not only exchange, store and process data but also collect it from nearby surroundings using sensors and effectively intercede on it using specified actuators [1]. In addition to this, users can take part in pushy framework by consuming and producing data using their various smart devices (smart phones, watches, etc).

With the strong disruptive character of IoT and the global dispersal of smart devices, the normal cities may eventually mutate into smart cities whose services and functions can be controlled and visualized for the advancement of citizens and their standard of life. In order to convert these ideas and services into reality, a huge amount of stored data need to be analyzed and the generated insights need to be retrieved. Though IoT cannot process the data including its delivery due to their limited resources (power, memory etc) [2]. To overcome this complication, the IoT devices need to shift their collected and computed data onto the web, thus utilizing its infinite resourcefulness.

It was 2012 when the concept of edge computing as introduced and later was termed as fog computing as a quintessential archetype to assist resource constrained IoT devices [3]. Fog computing doesn't substitutes the centralized cloud but cooperates with it and distributes cloud computing technologies (scalability, virtualization, etc) throughout the cloud and IoT continuum, at the edge of network in particular in close vicinity of the IoT devices [4]. Thus, in order to avoid the computation on faraway centralized cloud and offloading of data everytime, the smart devices can exploit and use the nearer, resourceful and cloud enabled nodes i.e. fog nodes. The propinquity of fog nodes and IoT devices in the invoking factor for various advantages which were not possible during the continual offloading to the cloud at distant place [5]. The basic characteristic advantages are listed below:

1. Latency: Predictable, least.
2. Bandwidth: Least consumption.
3. Privacy: Increased.
4. Context awareness.

Being relatively newest concept, fog computing therefore presents greater amount of issues and challenges that need to be interpreted and solved. Some of the characteristics, intriguing difficulties and open issues need to be elucidated so that the end devices will be furnished with support [6]. The fog computing's key features demand to be persistent in both situations i.e. when fog nodes are stationary or moving from one location to other location. The mobility of nodes compromises the fundamental features of fog computing because whenever a node moves, the distance between the fog node and the node itself increases [7]. Therefore, in order to keep the FAC close to the associated mobile node, the FAC needs to be migrated from one fog node to another. Besides the network issues themselves, the computational challenges get raised by mobility of nodes in a fog environment. In the research article, we scrutinize the challenges of mobility support in fog environment, emphasizing on discrete group of mobile nodes i.e. mobile IoT devices.

Providing mobility support is a mechanism of preserving the fog computing's special characteristics even if the mobile IoT devices keep relocating away from FAC (Fog Application Component). The nearness of fog to the end nodes have made all the above stated characteristics possible, now a little work of migration of FAC from a node of fog to another and maintaining its proximity to associated mobile IoT nodes. Sometimes the migration of fog services from node to another is not required. When the service is stateless, thus there is no need to maintain any stat. therefore, the target fog node can re- instantiate the fog service and redirect the associated nodes.

One more idea that needs to be understood is proximity or nearness doesn't mean geographical closeness, it simply means topological nearness. It is simple a transmission line between the FAC and IoT nodes that need to be kept short to maintain the characteristic features of IoT and Fog. Furthermore, sometimes physical maneuver of the end devices causes base station change, therefore substantative or visible changes between FAC and nodes need to be considered for such changes.

Keeping FAC close to its associated IoT node at the first keek may not seem to be a hard job to do but the fact is, it truly complicated than what it seems to be. Various distinct factors need to be taken into account as they may conflict with each other. These factors are given separate importance which vary from case to case and situation to situation as they fully depend on application requirements of the user and policies of the service provider. Few basic factors are:

- Quality of Service.
- Quality of Experience.
- Continuity of Service.
- Reliability and security.
- Efficiency in Bandwidth.
- Load Balancing.

The problem of migration of fog services is an issue of deciding where, when and how migration of services should take place so that the expected compromise between every considered factor can be achieved. One may suggest migrating consistently placing it to the most suitable fog node (topologically closest to IoT node's current position). However, it is appropriate to migrate the fog services habitually as every time the service is grated, it consumes bandwidth, CPU resources and implicates least of Time-Outs)when the service of fog nodes are unavailable).

As far as "where to migrate" is concerned, it means deploying FAC to fog node that is nearest to mobile IoT device topologically. However, the cost of migration towards that specific node and the nodes present amount of work to be done must be taken into account. Finally to decide "How to migrate" means the methods and technology that the system is going to use to execute the task of service migration. Every method might support few factors more as compared to other methods. Few methods are:

- Virtualization-Migrate Method
- The method used to recognize the group of feasible fog nodes.
- The method that deals with every changing transition of IP addresses of fog services and mobile nodes as they move respectively.

## 2. Related Work

Mobility support in a Fog Environment is a buzzword as the hot topic under consideration is doing rounds in the research arena. The issue is posing a lot of questions and queries that makes the study quite challenging. Moreover, the study of the issue might open doors for some valuable findings. In the following section, emphasis will be laid on mobile IoT in a Fog environment including mobile nodes.

The concept of Follow Me Cloud (FMC) [9] and lately that of Follow Me Edge (FME) [8] was put forth by Taleb et al. The two concepts help us to manage the relative service migration by managing the mobility of the nodes. Though the basic design was meant for cellular networks in supporting the mobility of the user, it proved helpful in utilizing the functionalities in 3G, 4G and 5G networks. The concept of FMC was improved in [10] so that mobile users from non-cellular networks like Wi-Fi could find support to get connected as well. In the case of FMC concept, Locator/ID Separation Protocol (LISP) is exploited and on the basis of Network Functions Virtualization (NFV), LISP elements are virtualized.

In order to effect migration decisions, Markov Decision Process (MDP) is a well-known framework for formulating service migration problems. In [11], Taleb et al proposed a distance based MDP where each state refers to Service Areas between the mobile user and the associated Fog Service and as such the user mobility is predicted by way of a single dimension mobility pattern. Another formulation of Service migration problem as a distance based MDP was proposed by Wang et al.[12] They put forth a 2D random walk mobility model which seems more realistic than the 1D mobility patterns. The authors came up with a new algorithm which differentiates itself from the standard one. Policy iteration minimizes the complexity from O(N3) to O(N2) where cardinality of the state space is represented by N+1. In [13], authors propose a system namely SEGUE which considers network and Fog Nodes States as the parameters which will effect migration decisions. SEGUE is a realistic system comprising of four cooperating modules. Two modules collect and analyze the important parameters and help in predicting QoSviolation, if any. In such an instance, MDP determines where to migrate the Fog Service. The migration is actually performed by the fourth module.

Wang et al provided an alternative solution in [14] by establishing a decoupling property of MDP which they put forward initially. It actually transforms it into two different MDPs on state spaces which are disjoint. Simple deterministic optimization problem thus obtained may be solved efficiently by applying Lyapunov optimization. Wang et al in [15] presented another work wherein they contextualized the mobility support issue in military environment. Owing to the strong security concerns, the authors came up with the ‘security cost’ in order to make migration decision along with transmission and migration costs. If the services of different users are hosted on the same physical node, the security cost of migration tends to increase. The problem has been modeled as an MDP [16] involving two users making access of two distinct services and moving as per 1D mobility pattern. As a simple way of addressing the problem, a modified version of the myopic algorithm has been proposed.

In spite of being the most common way to resolve the mobility support problem, MDPS are not the only one. Like in [17], the authors, in order to reduce the bandwidth consumption in a Fog enabled Vehicular Cloud Computing (VCC) have tried to make migration decisions. To solve the computational complexity, a polynomial time two phase heuristic algorithm is proposed.

In [18], authors have conceived an architecture in which a proxy Virtual Machine (VM) running various applications in the Fog environment have been associated to the set of IoT devices of a user. A part of the proxy VM relative to the devices is migrated when their subset moves together with the user. In order to minimize the band width consumption, migration decisions are actually made. Hence, for this purpose, the difference between the total traffic amounts generated in the network for not migrating and migrating.

## 3. Mobile IoT Scenarios

The number of connected devices in the huge complex web of internet is growing at an enormous rate and as quantitative reports the mobile devices at global level were 7.6 Billions, 8Billions in 2015, 2016 respectively and the predictions are that it will reach 11.6 Billion in 2021. Though our main concern is on sub group of mobile devices i.e. IoT devices. The mobile IoT is a growing process and forecasts are truly promisingly magnificent. The most appropriate examples of mobile IoT are wearable devices which were 325 millions in 2016 globally and the number will grow to 926 million by 2021. This greater number of mobile IoT devices can acquire uplifting advantages of fog computing to enable different services that in turn can improve human life dramatically.

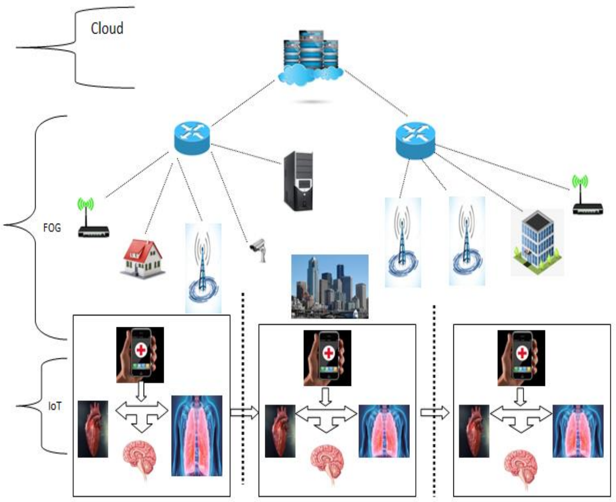


**Figure1.** Defined Scenarios

### 3.1. Healthcare of Citizen's

The basic scenario of citizen's healthcare is shown in figure 1. A single or multiple IoT devices are exploited to depict the parameters (Position, brain, heartbeat, breath, etc) related with a patient's health and respond with some necessary actions like mild electric shock, making an emergency call, etc). All these devices are connected to users (patients) smart phone (guided or unguided manner) which are operated using frontend application and the fog layer is deployed at the backend. It collects the data and performs rigorous computations to obtain decisive information and decide the action to be taken. The absolute readiness that is exploited to invoke these actions is of greater significance and sometimes can play a role in distinction of life and death. Also, the privacy of the data that is collected for decision taken has to be guaranteed because of being usually personal. Thus, it is important to maintain the fog app near to the patient wherever the patient moves in the city.

### 3.2. Smart Urban Surveillance using drones

The unmanned aerial vehicle - drones, cab ne used in various circumstances, specifically those which are unsafe for humans. The drones are considered less expensive than the aircrafts with pilots as drones do not need pilots to fly them. Most of the companies who deal with technology have started investing in drone technology and according to facts, figures and analysis mentioned in [8], the market for drone technology is going to reach more than 21 billion dollars by 2022. Till this date, the drones are controlled by users from remote places using controllers but a new series of drones are on their way which will be able to operate by themselves without user's involvement. All the processing need data collected to be analyzed formulate and execute the decision on board but this may affect the overall flight duration by consuming the battery power of the drone. These electronic calculations are exceptionally resource intensive, as data collected for analysation normally are streams of video and other types of data collected by sensors, where as the actions to carry out is to control drone and camera mostly but at some occasions to grab an object. To overcome this problem, the paradigm of fog computing fits the best in this situation. Nevertheless, the flying drones need the mobility support to make this kind of situation reliable for its use and outcomes. The propinquity of fog towards drone is specifically needed to save the bandwidth and allow least latency which can be predicted. Sometimes the drone itself can be regarded as fog node but in some rare situations to save its batter power.

### 3.3. Time Traveler Tourists

This scenario is an adaptation of an idea mentioned in [19]. One of the greatest and spectacular thought a human can experience is too the imperial cities like Athens, Sparta, Rome, etc. The tourists of modern world of technology can travel back in time by exploiting some characteristics of fog computing and IoT technology. Let us assume that a traveler travels to one of the above mentioned cities and boards a bus to take a tour of that city. The traveler wears a smart IoT enabled pair of glasses which recognizes the surrounding environment and films everything that the traveler is looking at. These smart glasses transfer this video continuously to its corresponding intrinsic application in the fog. Few resource intensive computations are performed at this intrinsic application in the fog, perceives what the traveler is looking at currently and responds with a reconstructed visual of how that specified place was in the past and projects on the smart glasses. Thus, it is extremely important that the FAP stays close to the traveler always, following his moves. Therefore, the requirement of greater responsiveness and greater bandwidth is perceptible.

## 4. Future Research Directions

***Proactive vs reactive service migration:*** Mobility of IoT nodes and availability of Fog services is preserved by keeping IoT nodes and Fog service topologically close. Transition of mobile device from one station to another (horizontal or vertical handover) causes change in topological distance. Therefore, when and where to migrate should be decided proactively or reactively, this is indispensable. Proactive decision is where fog service migration is done in advance by predicting the user's mobility and the method is inferable where overall performance benefits from it. The mobility prediction of user and vertical handover cab be stubby , may affect the overall performance. Reactive approach; where service migration is followed by handover. Thus , the dissimilarity among both handovers - horizontal and vertical is zero . Both the approaches should be investigated separately as well as combined, to effectively use both of the methods.

***Using context info to invoke service migration****:* Identifying the parameter based on which migration decision will be initiated. Parameter are selected based on real targets (e.g. Quality of Service, efficiency in bandwidth). Earlier work considered Network and System characteristics e.g.: State of network and fog nodes, exchanged data between apps cost of consumption of time and bandwidth. Nevertheless, context information enabled by fog is also considerable parameter, along with Network and System parameters.

***Enabling fog roaming by fog federation****:* It would be fascinating to form a federation of fog domains to explore the mobility support. Fog federation environment can improve mobility as users moves in to area where there are no nodes of its domains, in such case federated fog domains allow connection to is nodes. To implement such a federation there are considerable challenges need to be addressed, which has been not done yet, challenges such as management of service level agreements(SLAs) among fog domains, which architecture to be adopted either centralized of distributed and technologies which will enable this environment.

***Methods for migration and virtualization****:* Whether we consider migrate or virtualize both have impact on mobility performance and its applicability. Thus virtualization technology should be selected with many considerations, it should support maximum possible kinds of physical nodes to host fog service. Migration technique even plays a significant role in reducing the migration time and low time along with consumption of bandwidth. There exist many methods of migration (e.g. Mobile IP, Mobile IPV6, LISP, distributed mobility management) objective of these methods to provide ceaseless active session migrations. Even though, the scope and space for further exploration in this area exists.

***Compliance with existing interoperability platforms****:* Defining Reference architecture and APIs to implement mobility support solution, instead of from the scratch it would be better explore the existing standards and open platforms like M2M, FIWARE. It would be convenient to extended and append the features of proposed solutions. This will allow researchers significant and visible contribution.

***5G and mobile network integration***: ETSI (European Telecommunications Standard Institution) has defined mobile edge computing (MEC) as reference model for fog systems, it is the main and vital component in implementation of internet of things main services and 5G network. It would be a potential research path to initiate the support solution for Mobility as an integral component of European Telecommunications Standard Institution and MEC.

## 5. Conclusions

The paradigm of fog computing was introduced in 2012 to support resource constrained IoT devices in processing and delivery of information. The topological nearness of Fog to IoT devices enables numerous distinctive features which were impossible to attain when distant cloud was having offloading continuously. But the mobility of nodes is a big threat to these distinctive features preservation because the movement of nodes may give rise to the "compromised services" for the topological distance between the nodes, fog and the associated services. Thus, the later need to be shifted in order to follow the related IoT devices and maintain their topological nearness. In this paper, we have presented this idea in normal world's perspective by presenting three distinctive frameworks where it is extremely essential to support mobility. We have also explored in details the meaning of providing support to mobility in a fog and IoT environment, their associated fields and research directions.

## 6. Acknowledgement

The research was conducted at Prince Sattam bin Abdulaziz University, Alkharj- Saudi Arabia in the year 2018.

## References

1. *W. Zhou, Y. Jia, A. Peng, Y. Zhang and P. Liu, "*The Effect of IoT New Features on Security and Privacy: New Threats, Existing Solutions, and Challenges Yet to Be Solved,*" in* IEEE Internet of Things Journal.
2. M. Shaban and A. Abdelgawad, "A study of distributed compressive sensing for the Internet of Things (IoT)," *2018 IEEE 4th World Forum on Internet of Things (WF-IoT)*, Singapore, 2018, pp. 173-178.
3. P. Radanliev, D. De Roure, S. Cannady, R. M. Montalvo, R. Nicolescu and M. Huth, "Economic impact of IoT cyber risk - Analysing past and present to predict the future developments in IoT risk analysis and IoT cyber insurance," *Living in the Internet of Things: Cybersecurity of the IoT - 2018*, London, 2018, pp. 1-9.
4. H. Hejazi, H. Rajab, T. Cinkler and L. Lengyel, "Survey of platforms for massive IoT," *2018 IEEE International Conference on Future IoT Technologies (Future IoT)*, Eger, 2018, pp. 1-8.
5. I. Yen, F. Bastani, N. Solanki and Y. Huang, "Trustworthy Computing in the Dynamic IoT Cloud," *2018 IEEE International Conference on Information Reuse and Integration (IRI)*, Salt Lake City, UT, 2018, pp. 411-418.
6. A.Aljumah and T. A. Ahanger, "Fog computing and security issues: A review," *2018 7th International Conference on Computers Communications and Control (ICCCC)*, Oradea, 2018, pp. 237-239.
7. D. Roca R. Milito M. Nemirovsky M. Valero "Tackling IoT Ultra Large Scale Systems: Fog Computing in Support of Hierarchical Emergent Behaviors" in Fog Computing in the Internet of Things Springer International Publishing pp. 33-48 2018.
8. T. Taleb S. Dutta A. Ksentini M. Iqbal H. Flinck "Mobile Edge Computing potential in making cities smarter" IEEE Communications Magazine vol. 55 no. 3 pp. 38-43 March 2017.
9. T. Taleb A. Ksentini "Follow Me Cloud: interworking federated clouds and distributed mobile networks" IEEE Network vol. 27 no. 5 pp. 12-19 October 2013.
10. A. Ksentini T. Taleb and F. Messaoudi "A LISP-based implementation of Follow Me Cloud" IEEE Access vol. 2 pp. 1340-1347 September 2014.
11. A. Ksentini T. Taleb and M. Chen "A Markov Decision Process-based service migration procedure for Follow Me Cloud" IEEE International Conference on Communications (ICC) June 10–14 2014.
12. S. Wang R. Urgaonkar M. Zafer T. He K. Chan K. K. Leung "Dynamic service migration in mobile edge-clouds" IFIP Networking Conference May 20–22 2015.
13. W. Zhang Y. Hu Y. Zhang D. Raychaudhuri "SEGUE: Quality of Service aware edge cloud service migration" IEEE International Conference on Cloud Computing Technology and Science (Cloudf.om) December 12–15 2016.
14. R. Urgaonkar S. Wang T. He M. Zafer K. Chan K. K. Leung "Dynamic service migration and workload scheduling in edge-clouds" Performance Evaluation vol. 91 pp. 205-228 September 2015.
15. E. N. Ciftcioglu K. S. Chan R. Urgaonkar S. Wang T. He "Security-aware service migration for tactical mobile micro-clouds" IEEE Military Communications Conference (MILCOM) October 26–28 2015.
16. J. Plachy Z. Beevar and E. C. Strinati "Dynamic resource allocation exploiting mobility prediction in Mobile Edge Computing" IEEE 27th Annual International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC) September 4–8 2016.
17. H. Yao C. Bai D. Zeng Q. Liang Y. Fan "Migrate or not ? Exploring virtual machine migration in roadside cloudlet-based

vehicular cloud" Concurrency and Computation: Practice and Experience vol. 27 no. 18 pp. 5780-5792 December 2015
18. X. Sun N. Ansari "EdgeIoT: Mobile Edge Computing for the Internet of Things" IEEE Communications Magazine vol. 54 no. 12 pp. 22-29 December 2016.
19. 3. "MarketsandMarkets" Drones market worth 21.23 Billion USD by 2022 Mar 2017 [online] Available: http://www.marketsandmarkets.com/PressReleases/commercial-drones.asp.