IOT-Pattern-As-a-Service Model for Delay Sensitive IOT Integrated Applications

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Abstract: *At present, the Internet of Things (IoT) impacts heavily the daily lives of an individual in many domains, which ranges from wearable devices to industrial systems. Accordingly, these wide ranging IoT applications require application specific frameworks intended to carry out the operations in IoT applications. On other hand, IoT ecosystem evolves on integrating with other environments but the presence of heterogeneous devices in IoT integrated ecosystem groups the capacities in order to match the service requirements of users and to support wide users. Hence, a solution is required to synergize cooperation among the users in IoT integrated environment with great relevance. Along this line, the present work plans to adopt the IoT-Pattern-as-a-Service (IoT-PataaS) model to support Fifth Generation (5G) network environment, since the application is a delay-sensitive one and that should be controlled using high-end IoT devices. The proposed IoT-PataaS aims at provisioning IoT applications with reduced delay that leverages collaboration between the IoT objects in public and private clouds, which is present at the edge of 5G networks. The evaluation of IoT-PataaS model in 5G cellular network is carried out in terms of Narrowband IoT. The results claims that IoT-PataaS model obtains highly significant benefits in Narrowband IoT and LTE-A networks in terms of successfully delivered services in IoT platform.*

Keywords: *Internet of things, 5G network, delay-sensitive network, narrowband IOT, LTE-M and NB-IOT.*

Received December 5, 2019; accepted January 4, 2021
https://doi.org/10.34028/18/4/5

1. Introduction

The Internet of Things (IoT) is a promising technique that revolutionize the world through physical objects that are connected with each other [1]. The communication between the devices are made without any human interventions, hence it is necessary to provide seamless communication between the massive number of devices [12]. Further, the application of IoT in various fields needs to be updated frequently and to support the data storage, a low end-to-end cost cloud environment is used. The data communication between the devices and task processing and storage of data at cloud should be improved without any latency. Therefore, the IoT Cloud Provider [13, 17] is in need of a faster communication channel that should support the faster data rate, high computational capabilities and less end-to-end delay. This opens up a new market for massive integrated IoT applications [19]. The Fifth Generation (5G) services can support such massive devices and its associated services using massive Machine-Type Communications (mMTC), enhanced Mobile Broadband (eMBB) and Critical Communications and Network Operations. This supports well the basic requirements like low latency, high throughput and high scalability with massive device interconnection and provisioning of ubiquitous connectivity for end users [1]. However, as the load in next generation 5G mobile telecommunication due to social and economic development [9] IoT applications increases, the basic requirements pose serious challenges over IoT cloud provider. Thus, it degrades the user Quality of Experience (QoE) in IoT cloud provider with high cost [3]. Such constraints in IoT Cloud Provider is met by distributed cloud infrastructure involving network edge and devices on ground. Recently a solution has been developed [5] that reduces the latency and improves the QoE. With such objective from [3, 7, 10], we propose an integration of IoT cloud and 5G wireless communication for improving the task execution rate using Pattern as a Service (PataaS). This system is evaluated under three different scenario using vehicular networks.

The main contribution of the paper is given below:

- The author develops a significant contribution in the field of Narrowband (NB) IoT application using Pattern-as-a-service model in the field of cloud computing and then integrate it with IoT environment to support the 5G environment.
- The author develops a framework that is designed to match the service requirements of users and to support wide users of cloud computing by IoT and 5G network services that resolves the degradation in user QoE among the cloud providers with IoT framework.
- The IoT-PataaS methodology provisions IoT applications to leverages collaboration between IoT objects in public and private clouds with reduced delay at the edge of 5G networks.
- The IoT-PataaS methodology successfully delivers the PaaS services in Narrowband IoT and LTE-A

networks with high significant benefits.

The outline of the paper is presented here: section 2 provides the PataaS for Cellular IoT cloud providers. Section 3 discusses the 5G spectrum allocation for PataaS with Problem formulation. Section 4 provides an overview on 5G Spectrum allocation for PataaS. Section 5 evaluates the paper and section 6 provides discussion under three different scenarios. Section 7 concludes the paper.

2. Background

In current trend, the research focus on fulfilling the needs of IoT [25] by leveraging it with 5G wireless communications to support high end applications. It aims to design an IoT cellular system that supports low latency and high-reliability in IoT based Long Term Evolution (LTE) communications. The utilization of 5G communications aims at provisioning of internetworking among all IoT devices in order to provide high data rate, improved coverage, low latency and high spectral efficiency. There are various methods that addresses these issues.

Deebak *et al*. [10] developed IoT-Based Smart CAN (IoT-BSFCAN) framework to monitor an environment through cloud-enabled network. The results offer successful execution with reduced computation cost and communication fairness.

Xiong *et al*. [27] developed a multiauthority access control scheme in cloud for IoT that acts as a support authorization access for a user. This method offers reduced storage costs with computational overhead.

Wang and Cai [24] developed a rapid data retrieval in Internet-of-Things Cloud (IoTC) environment with named data networking. It helps IoTC to improve the retrieval of data in successful manner and reduces the costs.

Celesti *et al*. [8] focused on Tele-Rehabilitation as a Service (TRaaS) in cloud IoT services. The application of such technology with NoSQL DBMS(s) in healthcare big data [11] enables remote access with better performance than existing platforms.

Thakare *et al*. [23] designed an access control model in Azure IoT cloud. It enforces priority-based resource to multiple users in an organization that helps in reducing the ineffectuality and inefficiency with consistent policy implementation.

Sobhanayak *et al*. [22] used a task scheduling strategy to allocate the resources in cloud edge computing platform with IoT as its input data collection device. The performance enables maximum utilization of resources management [2] in edge network with reduced network congestion.

Qiu *et al*. [20] proposed a blockchain-based collective Q-learning approach to improve the Proof of Work with minimum percentage error.

Wu *et al*. [26] developed personalized federated learning framework in a cloud-edge IoT systems that mitigates the negative effects caused by heterogeneities. The edge computing with its fast-processing capacity and low latency enables effective computations.

Most of these methods failed to address the Third Generation Partnership Project (3GPP) standard, which is used to create a radio Narrowband IoT (NB-IoT) [16] technology that is designed to address the requirements of IoT networking. It is expected to improve the support the low-throughput, low power consumption and low delay sensitivity. Further, NB-IoT supports LTE to offload the traffic over NB IoT applications, which is a significant contribution in the field.

There is an agreement that NB-IoT boosts the application handling and 5G communication services. However, there exist certain concerns for empowering IoT devices effectively utilize over NB-IoT spectrum in order to meet the reliability and latency concerns. The solution is provided in the paper for NB-IoT spectrum and IoT spectrum to exploit their individualities for the IoT services.

3. PataaS for Cellular IOT Cloud Providers

In this paper, we consider the heterogeneous IoT cloud providers as a private user deployed by a service provider to form local resources. In the proposed framework, we introduce a main controller that manages the services and resources of the corresponding IoT cloud providers. The owner of IoT cloud providers registers the IoT devices based on the available services and resources. It also has the vision of the services offered based on available bandwidth resource of IoT cloud providers [14]. In order to manage the associations of various IoT cloud providers on demand, a PataaS model is deployed at the network edge. The compensator is accountable for implementing IoT cloud service policies for improved formation of patterns and its maintenance among IoT cloud providers [15]. It also scales the dimension of patterns rapidly based on the need of IoT cloud providers. The compensator implements the process of discovery and resource registration of new local IoT cloud providers. The status of compensator is further computed based on their network connectivity and utilization and it is updated further. The faster computation by the compensator leads to faster decision support by the PataaS. Hence, in a high-end IoT ecosystem, the fast decision by the core modules of PataaS is closely designed with to operate with IoT cloud providers.

With such aim, we consider cloud based 5G edge network for deployment of both IoT cloud providers with controller module and PataaS Compensator module as in Figure 1.

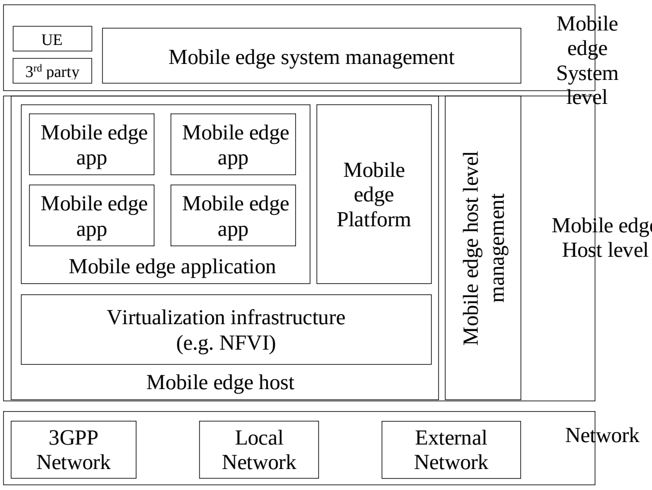


Figure 1. Mobile edge computing framework.

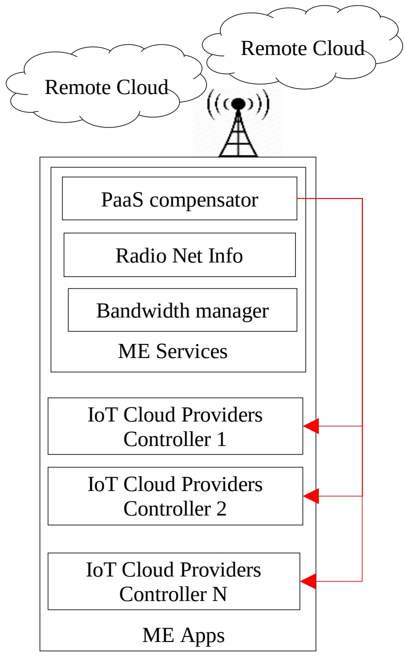


Figure 2. Proposed PaataS paradigm.

The integrated design of PataaS paradigm in cloud integrated 5G systems is shown in Figure 2. The edge host or access points of cloud integrated 5G network has a virtualization environment that provides storage, computation and resource for executing the applications of mobile edge platforms. Further, the IoT cloud providers controller is regarded as edge application, where it can make proper request to activate. The edge host offers edge services that supports edge applications with additional functionalities. The multi-access edge computing documents of Mobile Edge Computing framework Figure 1 some basic services like:

1. Radio network: exposing updated radio network information to the edge application.
2. Location: offering current served User Equipment (UE) location information to the host.
3. Bandwidth: allowing proper bandwidth allocation based on the routing to/from edge applications and providing priority to the routed traffic.

Depending of such mobile edge services, we hence envision a PataaS compensator as an additional edge services for IoT cloud provider controller in order to obtain proper services from IoT see Figure 2.

As per the PataaS paradigm, whenever a new task request is generated by a device application, the controller checks for the resource availability in IoT cloud providers in order to serve the incoming request. If the device application request is not served directly by the controller, then it generates a collaboration request and forwards it to the PataaS compensator of its edge host. The compensator running locally is accountable for making appropriate decisions about the formation of patterns w.r.t the generated request from all IoT cloud controllers. Further, the compensator checks the status of entire IoT cloud provider, which is interested in a pattern. Depending on the information collection, the compensator elects which available resource should resolve the new task request from various IoT cloud provider over a given pattern duration (pattern period). Finally, a new task list of ICP devices is generated and forwarded to an LTE scheduler that plans the requests based on latency constraints over the pattern period.

3.1. Pattern Management at Network Edge

Assume multi-edge mobile IoT cloud providers under a single LTE femtocell coverage area. The PataaS paradigm generates and priorities the patterns to increase the number of tasks executed in order to meet the Service Level Agreement (SLA) i.e., latency. The SLA is selected based on requirements to maintain the reliability of IoT services. To cope up with million IoT devices, the proposed system considers wild scenarios for analysis. In such scenarios, the successful tasks perform relevant interactions at the pattern period with specific timeline. The rate of success is increased by informing the compensator about the capabilities of devices and task requests in IoT cloud providers. With such details, the possible patterns for IoT cloud providers are created after mapping the cloud service requests onto the resource's availability. Such generation and mapping require the adoption of task allocation mechanism at the concentrator. A simple algorithmic model based on Orthogonal Super Greedy Algorithm (OSGA) [18] is used for mapping the request with available resource of the IoT cloud providers. Such IoT cloud providers are provided with preferences, since that assures reduced latency for the requested high-end services. In specific, the system adopts the following process:

- *Step* 1. The OSGA task allocation checks the existing allocated tasks.
- *Step* 2. The system checks for any possibility of reusing the allocated resources for serving the upcoming request.

- *Step* 3. Check if the allocated resources can be reused
- *Step* 4. Then existing services are used
- *Step* 5. Else if the existing allocated resources cannot be reused
- *Step* 6. Then newer services depending on totally served tasks and expected latency is found by sorting the total available nodes.
- *Step* 7. After sorting, the devices with lesser executed task and latency are chosen for increasing the chance of executed tasks meeting the requirements of Service-Level Agreement (SLA).
- *Step* 8. Check if the executed task guarantees the network load balancing or else go to step 3.
- *Step* 9. The OSGA assigns the task to the device (owned by IoT cloud provider).
- *Step* 10. Depending on the allocated task, the IoT cloud provider controller updates the status of resource availability w.r.t involved devices.

Considering the allocated services, selecting the optimal configuration of pattern IoT cloud provider is considered as a coalition formation problem. Each IoT cloud provider at this stage sets to maximize the usage of patterns. For each generated pattern, a priority value is associated with other patterns. The priority value is the difference between the utility obtained by IoT cloud provider and the total cost associated with resource sharing. The utility in IoT cloud provider depends on total executing tasks over the request tasks and total cost depends on the usage of resource to execute the tasks assigned over total available resources at IoT cloud provider. This study sets the priority of choosing cost and utility with equal weights to counterfeit the trade-off between cost and utility in sharing the own available resources by the IoT cloud provider. The game is available in patterns, since the network resources in cellular environment available for pattern generation depends on incoming resource request from other coalition for a given pattern. After computing the utility for each coalition, the compensator selects the best IoT cloud provider patterns to as per iterative switch operations in order to obtain stable patterns.

Observation from the service provisioning of devices in delay-sensitive applications requires a significant activation time. Hence, the service instances are setup by the involved devices, which allows the IoT cloud provider to send multiple requests at pattern period. This allows the IoT cloud provider to acquire timely responses from the other IoT cloud provider during the pattern period.

Assuming the exchange of data between the patterned IoT cloud providers occurs at edge node that takes into concern corresponding IoT cloud provider and the device communication. Hence, the device interoperability is agreed upon implementing appropriate semantic translations and syntactical translations. It is clear that with regards to mobility of the IoT cloud provider, edge nodes require communication between other IoT cloud provider to transfer the request or response of a task. In case of LTE-M setting, the X2 interface communications supports the communication between edge hosts. Obviously, the communication between the two edge hosts leads to introduction of delay during the delivery of services.

4. 5G Spectrum Allocation for PataaS

After determining the patterns and allocation of tasks in IoT cloud provider, the PataaS concentrator supports the patterned IoT cloud provider by exploiting edge services such as radio network, location and bandwidth information. Hence, it helps in managing the transmission of data to involved task in 5G.

The main aim of the proposed work is to resolve the problem of task and resource allocation within deadlines and with resource constraints. Certainly, the proposed system has given the total amount of resources with NB-IoT tones and Long Term Evolution for Machines (LTE-M) resource blocks (different capacities) to support the PataaS service. Each task possesses a total number of sending message within a specific deadline between any succeeding requests. The proposed system schedules the task in such a way that it meets the deadline constraints, radio resource constraints and hence it maximizes the total number of the solved tasks.

Further the proposed method overcome other challenges:

1. Various resources available for a same task over a specific deadline.
2. Sending multiple messages during a task over a specific deadline.
3. Different resource capacities with different data rates.

4.1. Problem Formulation

Assume IoT cloud provider $n \in N$ has a set of tasks $T(n)$ corresponding to a utility $u(n,t)$ acquired during task execution. Each task is allocated with patterns with several interactions between them within a pattern period $I(n,t)$. Consider a task t is executed successfully, then the entire interactions $I(n,t)$ (based on task t) is accomplished within the given deadline $D(n,t)$. Consider a binary variable $y(n,t,i)$ with unity value during the interaction i with task t in IoT cloud provider n, where the task is served successfully within the deadline $D(n,t)$. Hence, we define, $x(n,t) = \prod_{i \in I(n,t)} y(n,t,i)$. Specifically, the exchanges of messages during the interaction i with task t of IoT cloud provider n is referred as $M(n,t,i)$. The successful interaction of messages is identified using $y(n,t.i) = \prod_{m \in M(n,t,i)} z(n,t,i,m)$, where $z(n,t,i,m)$ is the unit binary variable when message m interaction i with task t in IoT cloud provider n. Such transmission is served successful, if and only if entire messages is sent over cellular interface. The LTE system in the proposed method uses frequency domain for message scheduling. So, the message is transmitted for a duration of 1ms using a single Time to Interactive (TTI). Additionally, the scheduling over NB is considered in the proposed method, hence we define the scheduling the messages over NB-IoT and LTE resources is given as

$$z(n,t,i,m) = a^{NB}_{n,t,i,m} + a^{LTE}_{n,t,i,m} \leq 1.$$

Similarly the time duration is expressed as $d(n,t.i) = \sum_{m\in M(n,t,i)} ET(n,t,i) + TTI \cdot z(n,t,i,m)$ that considers the execution time $ET(n,t,i)$. The total time slots available with each pattern period is F. During each TTI, the frequency resources availability for allocating resources in NB-IoT and LTE bands are represented as r_{NB} and r_{LTE} (i.e., total number of allocated resources) over entire R_{NB} and R_{LTE} (total available resources), respectively. Hence, the data transmitted by IoT cloud provider device n in a time slot s with single frequency resource out of total time slots F is given as $C^{NB}_{n,s}$ and $C^{LTE}_{n,s}$.

The main objective of the proposed system is to increase the total utility i.e., $\max \sum_{n\in N} \sum_{t\in T(n)} u(n,t) \cdot x(n,t)$ *s.t.* $d(n,t,i) \cdot y(n,t,i) \leq D(n,t)$, $\forall i\in I(n,t)$, $\forall t\in T(n)$, $\forall n\in N$ of IoT cloud provider under given constraints are formulated as,

$$\sum_{p\in R^{LTE}} C^{LTE}_{n,s} \cdot C^{NB}_{n,t,i,m,s,p} \geq L(n,t,i,m) r^{LTE}_{t,i,m} \ \forall t\in T(n),\ \forall n\in N,\ \forall m\in \underline{M}(n,t,i),\ \forall i\in I(n,t),\ \forall s\in F$$

$$\sum_{p\in R^{LTE}} C^{NB}_{n,s} \cdot C^{NB}_{n,t,i,m,s,p} \geq L(n,t,i,m) r^{NB}_{t,i,m} \ \forall t\in T(n),\ \forall n\in N,\ \forall m\in \underline{M}(n,t,i),\ \forall i\in I(n,t),\ \forall s\in F$$

$$\sum_{n\in N} \sum_{t\in T(n)} \sum_{i\in I(n,t)} \sum_{m\in M(n,t,i)} C^{LTE}_{n,t,i,m,s,p} \leq r_{LTE} \ \forall s\in r_{LTE},\ \forall s\in F$$

$$\sum_{n\in N} \sum_{t\in T(n)} \sum_{i\in I(n,t)} \sum_{m\in M(n,t,i)} C^{MB}_{n,t,i,m,s,p} \leq r_{NB} \ \forall s\in r_{NB},\ \forall s\in F$$

Where, N is the set of IoT cloud providers, $T(n)$ is the total set of tasks in each IoT cloud providers $n\in N$, $u(n,t)$ is the utility of an executing task t for IoT cloud providers n, $D(n,t)$ is the task deadline (in ms), $x(n,t)$ and $y(n,t,i)$ is the unity input and output binary variable for successfully served task, $I(n,t)$ is the interactions set, $d(n,t,i)$ is the interaction time (in ms), $M(n,t,i)$ is the set of exchanged messages, $z(n,t,i,m)$ is the binary variable with interacting message on IoT cloud providers. $ET(n,t,i)$ is the execution time, $L(n,t,i,m)$ is the message length (in bytes) related to its interaction with the task. $\frac{a^{LTE-M}_{n,t,i,m}}{a^{NB-IoT}_{n,t,i,m}}$ is the binary variable that represents the εsuccessfully served task over either NB-IoT or LTE-M bands, $\frac{a^{LTE-M}_{n,t,i,m,s,p}}{a^{NB-IoT}_{n,t,i,m,s,p}}$ is the binary variable that represents the radio resources for delivering the message m in time slots s over NB-IoT or LTE-M bands, F is the total number of TTIs in a pattern period. $\frac{r_{LTE-M}}{r_{NB-IoT}}$ is the number of allocated frequency resources for NB-IoT or LTE-M bands and $\frac{r^{LTE-M}_{n,s}}{r^{NB-IoT}_{n,s}}$ is the frequency resource capacity for NB-IoT or LTE-M bands.

The constraints associated for the problems in IoT cloud provider is given as follows:

1. The task is served successfully iff$d(n,t,i) < D(n,t)$.
2. For the message transmitted over LTE or NB-IoT band, the successful transmission of message should be guaranteed by entire capacities of allocated resource
3. For the pattern period containing TTIs, $r_{NB}<R_{NB}$ and $r_{LTE}<R_{LTE}$

4.2. PattaS Tasks Allocation over 5G Resources

The above section discusses the complexity of the given problem, which is a NP-hard problem. Hence, we consider an empirical model to allocate the tasks based on available radio resource in both LTE-M and NB-IoT. More specifically, the empirical model uses NB-IoT to allocate smaller resource and LTE-M to allocate larger resources using large block size. The proposed empirical model is given in Algorithm 1, where each task is computed based on utility and cost of radio spectrum. The former one request the IoT cloud provider during successful task execution and the latter one considers the exchange of data during pattern period. For each IoT cloud provider, the queue is created for task allocation over radio resource that is sorted in an order as per the available resource and utility function. The fairness among IoT cloud provider is guaranteed using multi-level queueing policy [6].

Algorithm 1: Task Allocation

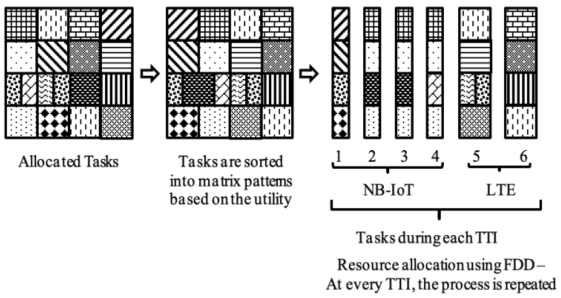
Data: Set of ICPs N
Result: radio Spectrum Allocation
Phase I – ICP Task Ordering:
For all n ∈ N do
For all t ∈ T(n) do
Compute the ratio between utility and radio cost for the task t;
End
Order the queue of tasks in a computed ratio;
End
Phase II: Task Scheduling Selection:
MTS=true;
While MTS= = true do
MTS=false;
For all n∈N do
If T(n), ϕ then

Select the task t on top of the queue T(n);
Allocate cellular resources for the t-th task;
T(n) ← t(n)\t;
If still resources available then
MTS = = True;
End; end; end; end

The present study uses three different radio resource configuration

1. LTE-M.
2. NB-IoT.
3. NB-IoT and LTE-M.

In the third case, initially, the tasks are allocated to NB-IoT and then based on the availability of resource in NB-IoT, the allocation on LTE-M band is either chosen or not. Such allocation of task is explained in Figure 3-a-, Figure 3-b) and Figure 3-c).



a) Allocated Tasks. b) Sorted tasks into matrix patterns based on the utility. c) The allocation of tasks over the LTE-M + NB-IoT radio spectrum.

Figure 3. Total allocation task using the PataaS.

5. Performance Evaluation

The network configurations for LTE-M and NB-IoT bands for task allocation is shown in Table 1. Then the network parameters are given in Table 2. The simulation is performed using matlab. An urban scenario is considered for the proposed study with an area of 750*750m. The LTE fem to cell or edge nodes are distributed in grid topology that are equispaced with a distance of 150m. The proposed system is tested in three mobility models i.e., static model, pedestrian model and vehicular model. The Levy Flight mobility model [21] is used in static mobility model with α=1 and random direction mobility model is used for vehicular mobility model. Finally, the vehicular patterns are characterized using random direction mobility model [7]. The execution of task is handled using six classes, namely, data caching, data offloading, warning messages, video streaming services, sensing and temperature for wearable devices with different packet size, TTI, latency requirements and time of execution. The proposed method is tested in four different configurations, namely,

1. Without PataaS.
2. Non-PataaS Edge.
3. PataaS.
4. PataaS Edge.

The total percentage of tasks severed i.e., successful delivery of task is estimated in terms of number of IoT cloud provider and pattern period.

Table 1. Network configurations of LTE-M and NB-IoT bands.

	LTE-M	NB-IoT
Bandwidth	180 KHz	1.4MHz
Peak data rate	< 100 Kbps	384 Kbps
Uplink and downlink speed	27.2 Kbps UL or 62.5 Kbps	Upto 1 Mbps
Latency	1.5-10 sec	50-100ms

Table 2. Network parameters.

Parameter	**Value**
Total number of executions Tasks in IoT cloud provider	3
Sensing types	4
Sensing units	[1-10]
Computation capacity/ cloud/ Edge node	[1-10] MFLOPS/ Unlimited/ 10 MFLOPS
Storage resource units/ cloud/ Edge node	[10-100] MB/ Unlimited/ 100 MB
Sensing resource units	[0-1]
Number of IoT cloud provider	[4-24]
Number of devices	3
Pedestrian Mobility model	Levy Flights
Vehicular Mobility model	Random Direction
Speed of Vehicles	45 km/h
Remote Cloud RTT	80 ms
NB-IoT bandwidth per RB	180 KHz
Number of subcarriers NB-IoT	288
Number of resource blocks in LTE-M	6
Total Simulation Runs	100

6. Results and Discussions

6.1. Nodes are Statics

The IoT cloud provider is organized inside a single edge node coverage that does not move over time. Hence, no fluctuations occur in the wireless channel and the performance of the system is constant over the entire federation period. Initially, the proposed system is tested for total successful tasks against different IoT cloud providers (see Figure 4). It is seen from the results that proposed PataaS model with could and mobile edge network performs well when compared with other configurations. The percentage of total number of successful tasks in NB-IoT bands are lower than another configuration, which is maintained around 75%. Similarly, the percentage of total number of successful tasks in NB-IoT + LTE-M and LTE-M configurations bands are is higher than NB-IoT configuration, which is goes till 100%. With increasing number of IoT cloud provider, the graph shows decreasing trend in task allocation in LTE-M and NB-IoT bands. This is due to poor availability of radio spectrum. However, the downtrend is not majorly reported in NB-IoT+LTE-M bands and it guarantees 100% successfully delivered tasks with PataaS model. The Figure 5 shows the percentage of tasks executed successfully against varying pattern period between 5s and 30s. In this case, total number of IoT cloud providers are made fixed as 24. The result shows that

NB-IoT+LTE-M obtains higher percentage of successfully completed tasks than NB-IoT and LTE-M. Further, NB-IoT+LTE-M supports more task even if the patterns increase. Further, since the vehicles are static in nature, the better channel conditions contribute to nil fluctuations in the system.

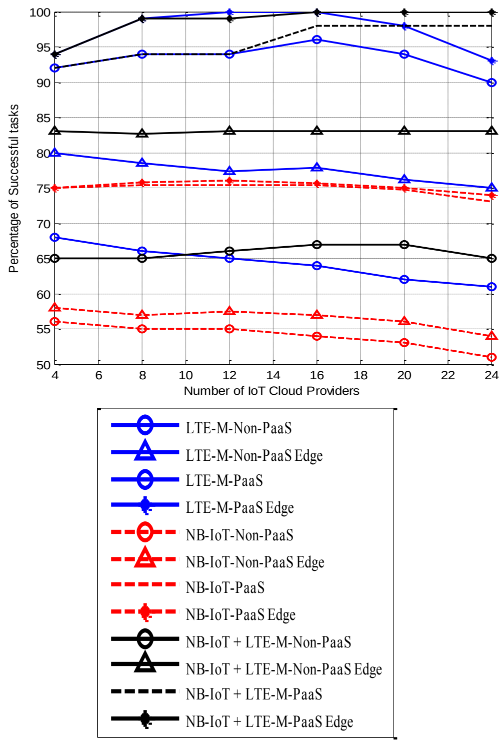


Figure 4. Successful tasks (in %) by varying IoT cloud provider in static scenario.

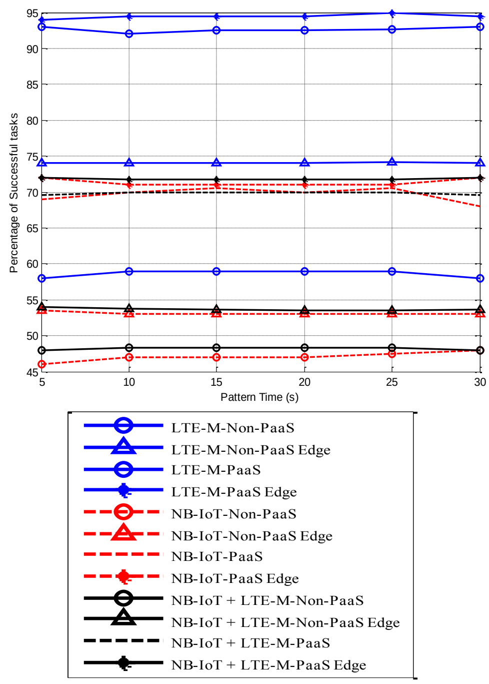


Figure 5. Successful tasks (in %) by varying pattern time in static scenario.

6.2. Pedestrian Scenario

The IoT cloud provider moves as per levy flight distribution, which experiences minor quality changes in channel at low speed compared with static scenario. The Figure 6 shows that successful rate of task executed has reduced w.r.t static scenario, assuming the pattern period to be 30s. The mobility leads to movement of IoT cloud provider across the edge node coverage area at the pattern period. The X2 communication links Round Trip Time (RTT) latency during edge interconnection. Further, delay gets increased when the message is transmitted between two different IoT cloud providers. Such constraints lead to failure in offloading the task and it exceed the deadline. The limited availability of spectrum reduces the success rate of task executed using NB-IoT+LTE-M to 85%. This is lesser when compared with static scenario but higher than average LTE-M (81%) and NB-IoT (67%) success rate. Since this method relies on cloud platform, the mobile edge services obtain improved performance. This is due to delay-tolerant nature of cloud during task delegation and this does not create any impact on successful offloading. However, NB-IoT fails to support the task offloading in cloud, since the cloud resources are consumed largely. This makes the non-PataaS Edge model to obtain reduced success rate than PataaS Edge model. The Figure 7 shows the percentage of tasks executed successfully in pedestrian scenario with constant IoT cloud providers, say 24. With increasing pattern period, the success rate of delivered task reduces. For instance, when two IoT cloud provider moves away from edge nodes, the longer pattern period leads to increased probability of missing the deadline. The result shows that NB-IoT obtains poor performance than LTE-M+NB-IoT and LTE-M. Further, NB-IoT+LTE-M supports more task even if the patterns increase, which increases the successful task to reach its maximum percentage i.e., 80%.

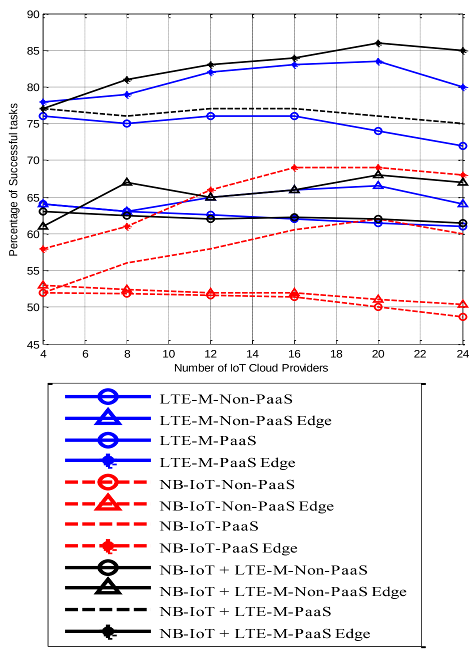


Figure 6. Successful tasks (in %) w.r.t varying IoT cloud provider in pedestrian scenario.

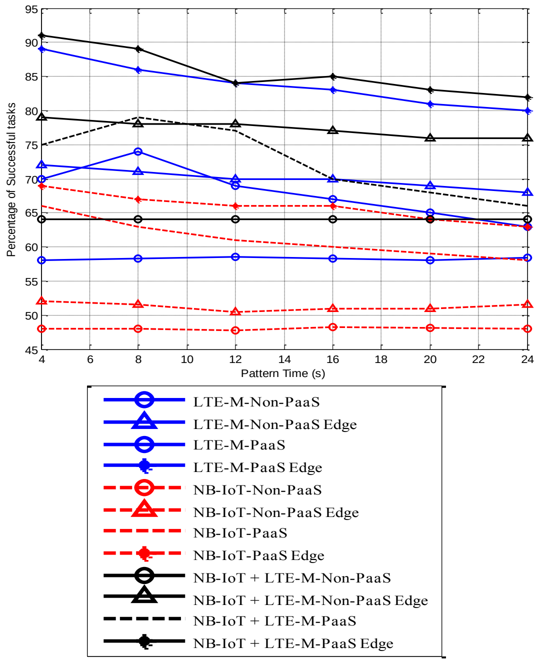


Figure 7. Successful tasks (in %) by varying pattern time in pedestrian scenario.

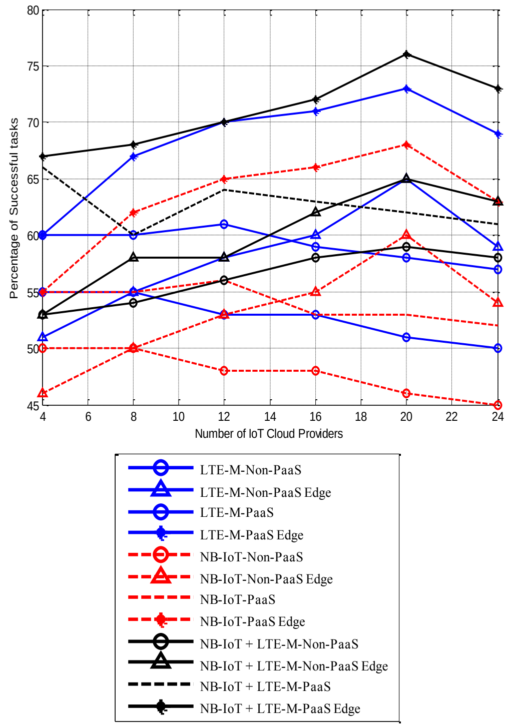


Figure 8. Successful tasks (in %) by varying IoT cloud provider in vehicular scenario.

6.3. Vehicular Scenario

Finally, the performance analysis is tested under vehicular mobility, where the IoT Cloud Provider moves with Random Direction mobility at a speed of 45 km/h. From the Figure 8, it is observed that vehicular mobility poses certain impacts on success rate. The LTE-M+NBIoT configuration obtains a higher percentage of successful task than other two configurations. A gain of 5% than LTE-M and 8% than NB-IoT configurations is noted. The success rate in vehicular scenario tends to reduce with increasing IoT Cloud Provider. Finally, the Figure 9 shows that percentage of tasks executed successfully in vehicular scenario with constant IoT cloud providers. The result shows that as the pattern period increases, the success rate of task executed recorded reduces. However, the success rate of NB-IoT is higher than LTE-M and LTE-M+NB-IoT configurations. The LTE-M+NB-IoT with PataaS edge configuration has higher successful task execution in all pattern period than other configurations. The Figure 7 shows the percentage of tasks executed successfully in pedestrian scenario with constant IoT cloud providers, say 24. With increasing pattern period, the success rate of delivered task reduces. For instance, when two IoT cloud provider moves away from edge nodes, the longer pattern period leads to increased probability of missing the deadline. The result shows that NB-IoT obtains poor performance than LTE-M+NB-IoT and LTE-M. Further, NB-IoT+LTE-M supports more task even if the patterns increase, which increases the successful task to reach its maximum percentage i.e., 80%.

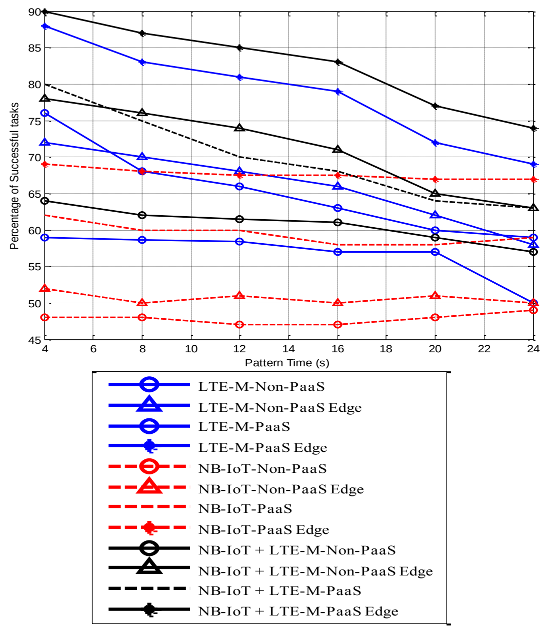


Figure 9. Successful tasks (in %) by varying Pattern time in vehicular scenario.

7. Conclusions

In this paper, we modelled PataaS model latency constraints under 5G cellular systems. Particularly, the evaluation is carried out in three mobility models with three different configurations. The evaluation is carried out by varying total number of IoT cloud providers and pattern period. The results showed that proposed method obtains increased execution of successful tasks under the combination of LTE-M+ NB-IoT than LTE-M and NB-IoT. Finally, it could be inferred that the present system is efficient in handling the traffic caused by high end IoT devices using LTE-M +NB-IoT. Thereby, it provides higher data rate with reduced latency.

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