Performance Analysis of a Priority based Resource Allocation Scheme in Ubiquitous Networks

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Abstract

It is difficult to perform resource allocation for a node with the agreed QoS requirement in a ubiquitous network, which consists of subnetwork segments of different technologies with different resource constraints and control. In this paper, we discuss performance analysis of a priority based resource allocation scheme for the Unodes, i.e., nodes running a ubiquitous application in a ubiquitous network. The proposed protocol exploits the advantages of both Static and Mobile Agents, by deploying them in different subnetworks (as and when required) to help the local administration to provide required network resources to the Unodes, and to ensure that the Unodes get the required network resources—by continuously monitoring their resource utilization and taking proactive actions. Mobile Agents (MAs) calculate the priorities of Unodes—by considering the importance of the application running on them, their resource utilization history and the cost effectiveness of the resource—and use those to allocate network resources among the contending Unodes fairly. We have built an analytical model of the proposed resource allocation scheme using queuing concept. The results obtained in the simulation and analysis reflects the effectiveness of the proposed scheme.

Keywords: Ubiquitous Network, Resource Allocation, Agents

1 Introduction

The ubiquitous computing applications promise to provide a variety of services uninterruptedly to the user anytime, anywhere and on any device without any request from the user [1, 2]. In order to enable such promising services, the underlying network (ubiquitous network), which consists of a set of heterogeneous subnetworks of different technologies like 3G, WLAN, WMax and Bluetooth, should support the traffic with different Quality-of-Service (QoS) requirements.

The basic resource allocation problem in a ubiquitous network shall address the Unode's (the node running ubiquitous applications) problem of getting resources in a foreign subnetwork. The objective of the resource allocation is to maximize the overall resources provided to the Unodes while ensuring that all the Unodes (and local mobile nodes) get their required (or at least minimum) network resources. To perform resource allocation for Unodes with the QoS requirement in a ubiquitous network is a difficult and challenging task as the network consists of set of subnetworks of different technologies with different resource constraints.

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1.1 Necessity of Resource Allocation

A ubiquitous system (or a ubiquitous application) tries to ensure that all its Unodes must get the required network resources throughout their service duration. Though the local administration (e.g., the Access Point (AP) in WLAN, and Base Station (BS) in GSM/GPRS) provids the network resources to the nodes present in its coverage area or its network, but it fails to differentiate between the Unodes, which has more resource constraints, and local mobile nodes, and to treat them differently, i.e., Unodes with higher priority. The main focus of the resource allocation in the ubiquitous network is to help the Local Administration (LA) of a subnetwork to provide network resources to the Unodes, and to take a special care of them so that the unavailability of the required network resources for a Unode can be avoided. The LA provides resources to all the nodes irrespective of whether they are Unodes or local mobile nodes. Although LA uses priority based resource allocation, but special care needs to be taken to make sure that all the Unodes get at least minimum of the required network resources.

In this paper, we propose a novel method for resource allocation for Unodes in a ubiquitous network using agents, which enable the LA of a subnetwork to provide the required resources to the Unodes. A Mobile Agent (MA), present in the subnetwork, achieves this objective with the coordination of the Static Agent (SA, which runs at the subnetwork where a ubiquitous application, or system, is initiated).

The rest of the paper is organized as follows: Section 2 discusses related works; Section 3 presents some of the definitions and notations used in this work; Section 4 and Section 5 present the ubiquitous node monitoring protocol, and the resource allocation problem in a ubiquitous network and the proposed priority based resource allocation procedure; the analytical model of the proposed scheme is given in Section 6; simulation procedure is presented in Section 7 followed by results and conclusion in Sections 8 and 9, respectively.

2 Related Works

Designing an efficient network resource management technique is a topic of intense research since the beginning of the networking paradigm. Now the focus of the resource management has shifted from managing a network to the ubiquitous network. Different ways of allocating network resources which have being discussed in literature are: a) Reservation-based resource allocation [3, 4, 5, 6, 7], where the QoS requirements are booked before the actual data transmission by sending signals through the data path; b) Prioritization-based resource allocation, where packets are marked to indicate the QoS requirements and send to the network [8, 9, 10]; c) Market-based resource allocation [11]; and d) Application-based resource allocation.

Resource reservation is not only essential to provide the required resources to a node to meet the QoS requirement but also to give higher priority (if required) to a migrating node (or handover call) than a starting node (a new call) [12]. Reserving resources in advance in heterogeneous networks is discussed in [13] that guarantees the availability of resources before the resources are needed. The proposed work is different to the reservation protocols such as RSVP [3, 6, 7] as the latter performs resource allocation on an “immediate” basis.

Scott Jordan et al [14] proposed a distributed pricing implementation that could be used in reservation-based QoS architectures. Both bandwidth and buffer along with delay and loss are considered for the proposed distributed pricing implementation. A pricing mechanism is discussed in [15] which takes into account the strategic behavior of wireless stations to allocate resources to multimedia applications. A price based approach to optimize the resource allocation in wireless ad hoc networks is discussed in [16].

The works in [17, 18] discuss auction based strategies for resource reservation, while advance resource allocation based on sequential ascending auctions in grid computing is proposed in [17], which enables users to share a different computing resources distributed over a network, and [18] proposes a progressive auction based market mechanism.

In [19], a proactive resource reservation method is discussed based on the inhabitant's most probable locations and routes. The work describes information-theoretic approach to manage the resources based on inhabitant's/user's mobility and location by analysing the daily lifestyle. The focus is more on location-aware resource management inside the house. Our work is based on analysing the path taken by predecessor and the personalisation information of the user. While their work is more focused on the indoor activity, where the resource availability is high, our work considers both interior and exterior activities, as the Unode roams across a set of heterogeneous subnetwoks (might be inside a campus), and competes for resources with the local mobile nodes.

Resource management frameworks in next generation have been discussed in [20, 21]. While the resource management framework for next generation wireless network discussed in [20] concentrates on the mobile cellular networks, in which an integrated resource management approach is proposed that can be implemented in next generation wireless networks to support multimedia services, a noncooperative game-theoretic framework for resource management is discussed in [21].

3 Definition

In this section we discuss some of the definition which are relevant for the discussion of resource allocation in ubiquitous networks:

- *Agents:* They are autonomous programs that execute on a node, and perform actions on behalf of the user (or application). The interesting features of agents are autonomy and adaptability. Mobile agents are the special type of agents, with mobility features, who travel from node to node resuming their execution. Hence, they are not bound to the node where they were created or started execution for the first time. There are many mobile agent platforms available those offer services like execution, communication, mobility, tracking, directory, persistence and security to their agents. An execution environment provided by the platform is the most basic service which allows agents to run their code. Contract Net Protocol and Dutch Auction Protocol are the agent interaction protocols standardized by FIPA (Foundation of Intelligent Physical Agents), which can be used between FIPA complaint agents for communication. [22]

- *Ubiquitous Network:* It is a fundamental part of ubiquitous computing, and is a set of heterogeneous subnetworks with technologies such as WLAN, Bluetooth, WMax, cellular network and sensor network. It provides uninterrupted connectivity to the users anytime, anywhere and on any device on any network technology. According to Teruyasu Murakami [23], from user's perspective, the ubiquitous network must provide access to the broad-band network to the user from literally anywhere.

- *Ubiquitous Application:* An application which provides the services to a user in a ubiquitous computing environment is called as a ubiquitous application. A ubiquitous application should have the following desirable characteristics: a) the ubiquitous application needs to be adaptable both in terms of application architecture adaptability, i.e., structure of the application (the configuration of the components that constitute the application), and application data adaption, as the application might require to run on different devices with different device properties [24]; b) the application also needs to be mobile to transfer application ownership among devices; and c) the applications needs to be context aware to customize their behavior to the particular user's situation or environment.

- *Local Administration (LA):* The Access Point (AP) in a WLAN subnetwork, Base Station (BS) in a GSM/GPRS are considered as local administrators, as they administrate the data/information flows inside their coverage area. Each of them provides network resources to both the Unodes and local mobile nodes, and assists the MA (or SA) in allocating the required resources to different Unodes by providing network resources (and information).
- *Unode:* A node running a ubiquitous application is called as Unode. The service requirement specification, the service request, the service provision, the resource requirement request, etc., are generally done by the central ubiquitous system—which administrates the ubiquitous application—than the node itself.
- *History of the Unode:* As the history of a Unode, which includes its past movement and resource consumptions, is very much useful to analyse the Unode's past behavior, we consider the Unode's resource utilization history, migration or mobility pattern and the path followed by the predecessor Unodes to analyse and to predict the most probable subnetwork where the Unode might migrate and the resource requirement of the Unode.

4 Unode Monitoring Protocol

In our previous work [22], we have designed an agent based monitoring protocol to monitor the Unodes. The agent coordinates with LA of a subnetwork to provide required network resources to the Unodes, and monitors health condition of the Unodes by collecting their resource utilization information from LA.

The use of agents in ubiquitous computing has been shown in [25, 26], by using them for intelligent content delivery and for context-aware ubiquitous computing services respectively, this motivated us to use them for the monitoring of Unodes, and also to address resource allocation problem. The main segment of the monitoring protocol runs at the central ubiquitous system with SA. SA plays a significant role in the node monitoring protocol, by coordinating between different modules of the monitoring system, to monitor the resource utilization of the Unode. SA not only predicts the subnetwork to which the Unode might migrate; but also generates and dispatches an MA into the next (predicted) subnetwork—prior to Unode's migration into the next subnetwork—with Unode's resource requirement information.

MA contacts the LA of the subnetwork, and reserves the resources for the Unode. When the Unode enters into the subnetwork, MA informs the Unode about the resource reservation. Then the Unode starts getting the information (ubiquitous application information), and MA monitors the resource utilization of the Unode by gathering the resource utilization information from LA. MA analyses the information and reports back to the SA.

5 Proposed Resource Allocation Scheme

The main objective of the resource allocation scheme in a ubiquitous network is to provide the required network resources to the existing (or newly migrated) Unodes in a subnetwork of the ubiquitous network. The allocation of required resources to the Unodes means that MA (or SA) assists LA of the subnetwork to provide the required resources to the Unode without affecting (much) the resources used by the existing Unodes and the local nodes, i.e., not resulting service degradation in the subnetwork.

The scheme will broadly function as follows. When a session starts at a subnetwork where the main ubiquitous application has been initiated, the Unode is allocated the required resources (for example, data rate r_s in bits per second), i.e., LA provides the required resources to the Unode with coordination of SA. Here, we assume that the LA in each subnetwork has sufficient resources to provide at least the minimum required resources to the existing Unodes. SA informs LA, using Remote Procedure Call (RPC) mechanism, to establish a RSVP connection (with resource requirement of Unode) with the central ubiquitous application running system, and to provide the gathered information to the Unode. Before migration of a Unode into a subnetwork, we adapt the following procedure for resource allocation, for each of the Unode migrated and/or about to migrate into the subnetwork, the resource allocation module—present at the subnetwork where the ubiquitous application is initiated—provides resource requirement information to the SA [22]. The SA generates and dispatches an MA into the next subnetwork with resource requirement information, if there is no MA in the subnetwork (MA shall exist in the subnetwork if there is a Unode of the same application) otherwise, informs the existing MA in the next subnetwork. MA interacts with LA to reserve the resources for the Unode by establishing a new RSVP connection with the central ubiquitous application running system, and informs the Unode (shown in Fig 1). The important issue is that once the Unode is allocated the required resources, in a subnetwork, it is not guaranteed that it would get required resources throughout its service duration because of potential network abnormalities in the subnetwork, like network resources degradation and network breakdown. So it's the responsibility of the MA, present in the subnetwork, to distribute the available resources of LA among the Unodes so that each Unode's (or at least) minimum requirements can be met. Another important function of the protocol is to inform SA to use the history of the application, Unode and network to modify the Unode's requirement to provide the required service, during the unavailability of resources at the LA.

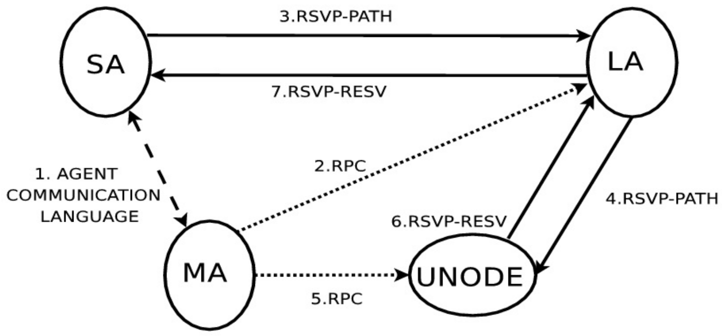

Figure 1: Resource allocation in a subnetwork

The phases of the resource allocation scheme are:

- SA predicts the subnetwork where the Unode might migrate.
- It then generates and dispatches MA to the next subnetwork.
- MA takes all the Unodes' resource requirements with equal priority and negotiates with LA to allocate (at least) minimum resource requirement to the Unodes.
- MA generates the priority to be assigned to the Unode, and distributes the left over resources of LA, after providing the minimum resources, among contending Unodes based on priority.

We discuss diffrent phases of the scheme in following subsections.

5.1 Prediction of Unode Migration

Prediction of user mobility assists handoff management, resource allocation (in advance) and service reconfiguration [27]. If the location of a Unode is known, which can be estimated from the Received Signal

Strength Indication (RSSI) value or by using location estimation method [28], then we can predict the next subnetwork the unode might migrate based on its (Unode's) past travelling pattern and predecessor Unodes' travelling pattern.

If a Unode has taken a path in the past for a particular purpose, the probability that the Unode will take the same route for the same purpose is high, for example, a person taking a particular route to go to office everyday, passing through the subnetworks, will chose the same path (with higher probability) to go to office in future also. Similarly, the path taken by a predecessor Unode can be helpful to predict the subnetwork to which a Unode might migrate, for example, in a ubiquitous museum application most of the visitor of Astronomy interest will follow same path, so the subnetwork they visit also same.

5.1.1 Unode History Analysis

Considering the above mentioned cases, we predict the next subnetwork that the Unode might migrate. Let **UM** and **PM** are the sets of subnetworks into which the Unode has migrated and the predecessor Unodes have migrated, in the past, from the current network respectively, i.e.,

$$\begin{aligned} \mathbf{UM} &= \{um_1, um_2, ..., um_x\} \\ \mathbf{PM} &= \{pm_1, pm_2, ..., pm_y\} \end{aligned} \quad (1)$$

where um_1 is a subnetwork that Unode has migrated in the past and pm_1 is a subnetwork that the predecessor Unodes have migrated from the current subnetwork; and x and y are the number of subnetwork into which the Unode might migrate. Let $\mathbf{P_u}$ and $\mathbf{P_p}$ are the sets representing the probability of migrating to these subnetwork, from the current network, and are associated with the set **UM** and **PM**, i.e.,

$$\begin{aligned} \mathbf{P_u} &= \{p_{um_1}, p_{um_2}, ..., p_{um_x}\} \\ \mathbf{P_p} &= \{p_{pm_1}, p_{pm_2}, ..., p_{pm_y}\} \end{aligned} \quad (2)$$

If

$$(\tau)max(\mathbf{P_u}) \geqslant (1-\tau)max(\mathbf{P_p})$$

where τ is an application dependent weighing factor, which would be small for applications like ubiquitous museum application where the path followed by the predecessor Unodes is important; and high for applications where the usual path followed by the user is important. Then, the subnetwork corresponding to the $max(\mathbf{P_u})$ will be the chosen network. Otherwise, the network correspond to the $max(\mathbf{P_p})$ will be the chosen network. Algorithm 1 shows the Unode migration prediction done by SA.

Algorithm 1: Prediction of subnetwork into which Unode might migrate (by SA)

```
Data: UM, PM, P_u, P_m, τ
Result: x (the predicted subnetwork)
if (τ)max(P_u) ⩾ (1 − τ)max(P_p) then
    x = um_i such that p_{um_i} = max(P_u) where i ∈ UM ;
end
else
    x = pm_i such that p_{pm_i} = max(P_p) where i ∈ PM ;
end
```

5.2 Derivation of Priority values

The priority values of a Unode represents the degree of importance given to a Unode [29]. In this paper, the priority values are dynamically adjusted in different sessions such that each Unodes resource requirements can be satisfied, and the total resources can be utilized efficiently. We define a session as the duration during which the total number of Unodes does not change. A session changes when a new Unode arrives, or an old Unode departs, or an existing Unode stop execution. For a session the priority values and priority quotients are calculated. Accordingly, the priority value of a Unode i is given by

$$P_i = \left\lceil \sum_v l * \frac{P_{i,v}}{|V|} \right\rceil \tag{3}$$

where $P_{i,v}$ represents the priority assigned to Unode i based on v ($v \in V$), V={application running on the Unode i, resource utilization history of Unode i for an application, cost effectiveness of the application running on the Unode i }, and l is the number of levels of priorities (in our case l=10). $\lceil . \rceil$ is the ceiling function. If U and N represent the total number of Unodes present in a subnetwork and the number of resources available at LA respectively, then the priority values can be assigned to different Unodes based on v.

5.2.1 Priority assignment based on the application running on Unode

The priority value is assigned to a Unode based on the number of subnetworks it has migrated and the type of application running on it. We assumed that a Unode which has migrated several subnetworks is much more important [30] than the Unode which has travelled few subnetworks. As the user (who uses the Unode) will be more annoyed if he/she does not get the service than the the user who is just about to start receiving a service. If H_i represents the number of hops Unode i has taken before reaching the present subnetwork, then, H_{max}, i.e., the maximum number of times a Unode has migrated among all Unodes, can be defined as

$$H_{max} = max\{H_1, H_2, ..., H_U\} \tag{4}$$

The priority of the Unode i, $P_{i,application}$, can be calculated by

$$P_{i,application} = \delta_i \frac{H_i}{H_{max}} \tag{5}$$

where δ_i is a parameter which considers the importance of Unode; $0 \leqslant \delta_i \leqslant 1$. The highest priority is assigned to the Unodes those have migrated into most of the subnetworks of a ubiquitous network compared to other Unodes, and lowest priority to the Unodes those have travelled least number of subnetwork.

5.2.2 Priority assignment based on Unode's resource utilization history

The information available on the past activities of a Unode can be used to assign priority values. If a Unode has not utilized the assigned resources properly in past then it gets less priority than the Unode which has utilized the assigned resources. If $\alpha_{i,j}$ represents the percentage of j_{th} network resource utilized by the Unode i, then the priority value can be defined as

$$P_{i,history} = \sum_{j \in I_i} \frac{\alpha_{i,j}}{|I_i|} \tag{6}$$

where, I_i is the set of required resources of Unode i. Here, we assume, if a Unode is malicious and it is intent to sabotage the system, then it can be easily detected, and minimum resources will be allocated to the malicious Unode.

5.2.3 Priority assignment based on the cost effectiveness of the resource

The Unodes seeking for high demand resources will be given lower priority while compared to the Unodes which require low demand resources. Let U_j is the number of Unodes requesting for j_{th} resource, and U is the total number of Unodes present in the subnetwork. We define, $\beta_{i,j}$, the percentage of Unodes seeking j_{th} resource as

$$\beta_{i,j} = \frac{U_j}{U} \tag{7}$$

Then for Unode i the cost effective priority can be defined as

$$P_{i,cost} = \sum_{j \in I_i} \frac{(1-\beta_{i,j})}{|I_i|} \tag{8}$$

Algorithm 2 shows priority values of Unode i derived by SA.

Algorithm 2: Derivation of Priority values

Data: $H_i, V, \delta_i, \alpha_{i,j}, I_i, U_j$ where $i = 1,2,...,U$ and $j = 1,2,...,N$
Result: P_i (the priority value of a Unode i in the subnetwork)
$P_{i,application} = \delta_i \frac{H_i}{H_{max}}$ where $H_{max} = max\{H_1, H_2, ..., H_U\}$
$P_{i,history} = \sum_{j \in I_i} \frac{\alpha_{i,j}}{|I_i|}$
$P_{i,cost} = \sum_{j \in I_i} \frac{(1-\beta_{i,j})}{|I_i|}$
$P_i = \left\lceil \sum_v l * \frac{P_{i,v}}{|V|} \right\rceil$

5.3 Resources Distribution Estimation by MA

In a subnetwork of a ubiquitous network, MA distributes the available resource of LA among contending Unodes. Here, we assume that LA has sufficient resources for the Unodes most of the time. Provided that each Unode has some minimum, $R_{i,j}(min)$, and maximum, $R_{i,j}(max)$, resource requirement, MA tries to distribute the highest amount of network resources to a Unode while maintaining other Unodes' resource requirement, by providing the minimum resource requirement of the Unode initially, and increasing it gradually.

Before a Unode's migration takes place, the previous resources distribution of the network has to change to allocate the required resources to the newly migrating Unode. If the available resources of LA are adequate to provide the required resources to the migrated Unode, MA allocates the required resources to the Unode. Otherwise, MA reduces the quantity of resources provided to the existing Unodes, while ensuring that it would not result in their service degration, till it (MA) gets sufficient (or necessary) resources for the new Unode.

The allocation of the required resources to a migrating Unode takes place before the actual migration to ensure that the Unode will get the required service as soon as it enters the subnetwork, which makes the service provision seamless; and after the migration to provide the required resources to the Unode through out the service duration. This is accomplished by MA, based on the prior information it has received from SA regarding the Unode migration to its (MA) subnetwork.

Let $R_{i,j}$ is the j_{th} resource requirement of the i_{th} Unode, where $R_{i,j} \in [R_{i,j}(min), R_{i,j}(max)]$.
For example, $R_{i,j} \in 4-13kbps$ for an audio application; U and N represent the number of Unodes and

the number of resources available for the application in a subnetwork of the ubiquitous network. Based on the amount of available resources of LA, the number of Unodes present in the subnetwork and the maximum resource requirement of each Unode, we can have two cases:

- case 1:

$$\sum_{i=1}^{U} R_{i,j}(max) \leqslant R_j(available) \forall j = 1,...,N \tag{9}$$

In this case, MA allocates maximum amount of the resources to each Unode, i.e.,

$$R_{i,j} = R_{i,j}(max) \tag{10}$$

and informs the same to LA and Unode, so that LA can provide the maximum required resources to the Unode.

- case 2:

$$\sum_{i=1}^{U} R_{i,j}(max) > R_j(available) \forall j = 1,...,N \tag{11}$$

In this case, MA allocates the resources optimally among the contending nodes based on their priority. If $L_j = [R_{1,j}(min)R_{2,j}(min)...R_{U,j}(min)]'$, $U_j = [R_{1,j}(max)R_{2,j}(max)...R_{U,j}(max)]'$ and $R_j = [R_{1,j}R_{2,j}...R_{U,j}]'$ then an efficient allocation of a resource among contending Unodes can be characterized as an optimal solution of the following optimization problem:

$$\begin{aligned} \text{maximize} \quad & Q_j \\ \text{subject to} \quad & L_1 \leq R_1 \leq U_1, \\ & \sum_{i=1}^{U} R_1(i) \leq R_1(available). \end{aligned} \tag{12}$$

Where $Q_j = \sum_{i=1}^{U} q_i \log(R_1(i))$ and $R_1(available)$ is the amount of resource 1 available at LA. q_i is the priority-quotient, and $q_i = \frac{P_i}{l}$ (see 5.2) where $l = \sum_{i=1}^{U} P_i$ and $R_1, L_1, U_1 \in \Re^U$.

Similar to the single resource optimization problem, the optimization problem for multiple resources can be computed as:

$$\begin{aligned} \text{maximize} \quad & Q_1, Q_1, ..., Q_N \\ \text{subject to} \quad & L_j \leq R_j \leq U_j, \ j = 1, \dots, U \\ & \sum_{i=1}^{U} R_j(i) \leq R_j(available), \ j = 1, \dots, U \end{aligned} \tag{13}$$

6 Analytical Model

We have built an analytical model of the designed resource allocation scheme using queuing concept. We have evaluated the blocking probability of a Unode, i.e., the unode is not provided the required resources, with priority p, i.e., class-p Unode using, $M/M/k/k$ multi-service loss model. If we assume that LA has

Table 1: Parameters used in analysis and their definition

Parameter	Definition
p	Number of priority level, or class of Unodes.
k	Total number of servers.
n_i	Number of class-i Unodes in the system for i=1,2,...,p.
s_i	Number of servers used by a class-i Unodes
λ_i	Mean arrival rate of class-i Unodes.
$\frac{1}{\mu_i}$	Mean holding time of s_i servers.
A_i	λ_i/μ_i

allocated few servers, k, to the MA, then MA needs to distribute among the contending nodes based on their priority.

Table 1 shows different parameters and their definitions, used in the proposed multi-server loss model. Let **n** and **s** be the sets of number of class-i Unodes in the system and the number of servers used by a class-i Unode, i.e., $\mathbf{n} = \{n_1, n_2, ..., n_p\}$ and $\mathbf{s} = \{s_1, s_2, ..., s_p\}$. Then **ns** is the number of busy servers. We consider an P-dimensional continuous-time Markov chain where the state space is defined by all feasible vectors **n** each of which represents a P-dimensional possible state of the system. **n** is feasible if the number of busy servers are less than the available servers. Let **F** be a set of all feasible vectors. We derive the blocking probability of each class by deriving the state probability vector

$$p(\boldsymbol{n}) = p(n_1, n_2, ..., n_p) = \frac{\prod_{i=1}^{P} \frac{e^{-A_i} A_i^{n_i}}{n_i!}}{\sum_{\mathbf{n} \in \mathbf{F}} \prod_{i=1}^{P} \frac{e^{-A_i} A_i^{n_i}}{n_i!}} \tag{14}$$

Let $\mathbf{F}(p)$ be the set of the states in which an arriving class p customer will not be blocked, i.e., $\mathbf{F}(p) = \{\mathbf{n} \in \mathbf{F} | \mathbf{ns} \leq k - s_p\}$.
Then the blocking probability of class p customer is:

$$B(p) = 1 - \frac{\sum_{\mathbf{n} \in \mathbf{F}(p)} \prod_{i=1}^{P} \frac{e^{-A_i} A_i^{n_i}}{n_i!}}{\sum_{\mathbf{n} \in \mathbf{F}} \prod_{i=1}^{P} \frac{e^{-A_i} A_i^{n_i}}{n_i!}} \tag{15}$$

7 Simulation

In the simulation we have considered three different subnetworks, i.e., 3G, WLAN, and Bluetooth (BT) technologies as the segments of a ubiquitous network. A ubiquitous application has been activated in one of the subnetworks with 20 Unodes. These Unodes travel in random directions and need the local resources. We assumed that a Unode works in these three different networks segments. A Unode's minimum resource requirement varies from 2 to 7 kbps, and maximum from 8 to 18 kbps; and all the nodes migrate between these subnetworks while getting the information, and the amount of network resource 3G network provides is lesser than that of the WLAN and BT. The assumption is based on the fact that in 3G subnetwork, the number of local mobile nodes, getting services, is quite higher than that of the WLAN and BT. We have only considered the downlink.

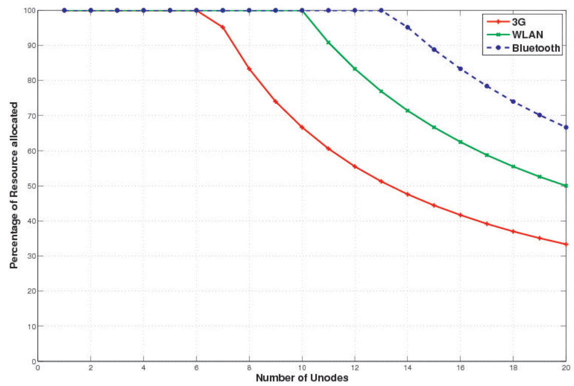

Figure 2: Resource allocation in different subnetwork Vs. Number of Unodes

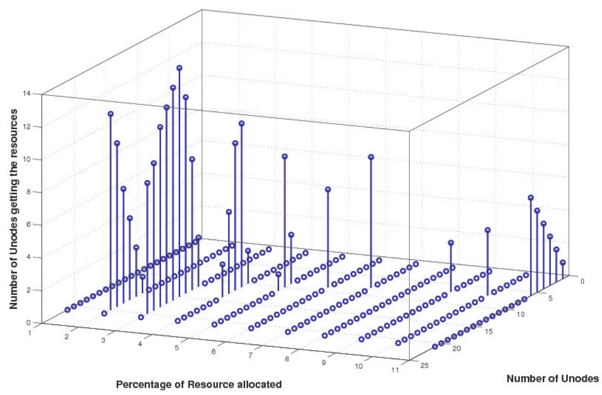

Figure 3: Distribution of resources among Unodes with equal priority in 3G subnetwork

8 Results

The result of the simulation is shown in the Fig. 2; where the x-axis shows the number of Unodes; and y-axis shows the percentage of the resources allocated to the Unodes. The plot shows that the resource allocation among Unodes decreases as number of Unode increases. The distribution of the resources in 3 different network is also shown, which shows that the BT and WLAN can provide better services than the 3G when the number of local mobile nodes is higher than that of the Unodes. Fig 3 shows the resources distribution among the Unodes (considering equal probability in 3G subnetwork) where, as can be observed, the percentage of resources allocated to the Unode decreases as number of Unodes increases. The x-axis, y-axis and z-axis represent the number of Unodes, the percentage of the resource allocated and number of Unode getting resources respectively. For clarity we have considered 1 unit as 10 percentage of the maximum required resource. Here, we can observe that till the total number of Unodes are 6, each Unode was getting the maximum amount of the required resources. When the number of Unodes exceeds 6, the total available resources at LA is not sufficient to provide maximum required resources to the Unodes, so it has been divided among all the Unodes equally.

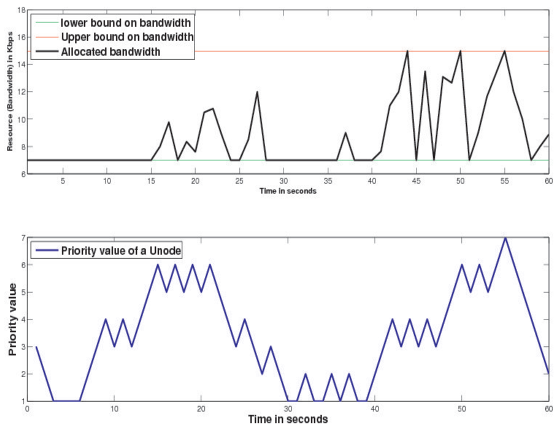

Figure 4: Resource allocation of a Unode based on its priority in 3G subnetwork

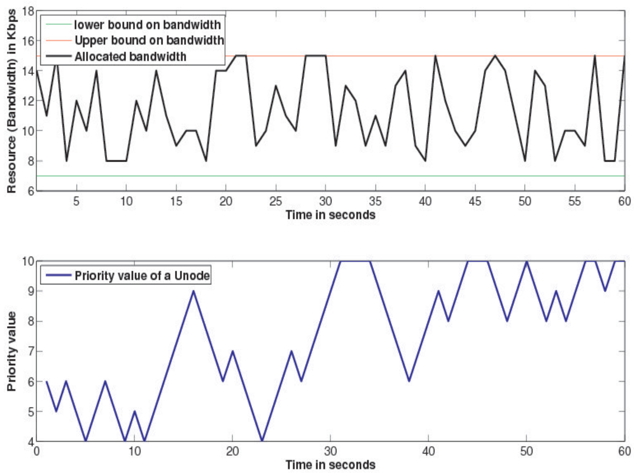

Figure 5: Resource allocation of a Unode based on its priority in WLAN subnetwork

Fig 4 and 5 show the resource allocated to a Unode by the MA/SA in the 3G and WLAN subnetwork. The graphs show the resource allocated to a Unode based on the priority assigned to it. The resource allocated to a Unode is shown in the top plot, while the priority assigned to the Unode (dynamically) is shown in the bottom plot. As we can observe, MA allocated minimum required bandwidth to the Unode when its priority value is the lowest, and tried to provide Unode's maximum bandwidth requirement when the priority value is highest.

Fig. 6 and 7 shows the allocation ratio and the fairness index of the proposed resource allocation algorithm in 3G and WLAN subnetwork. The allocation ratio represents the average percentage of the

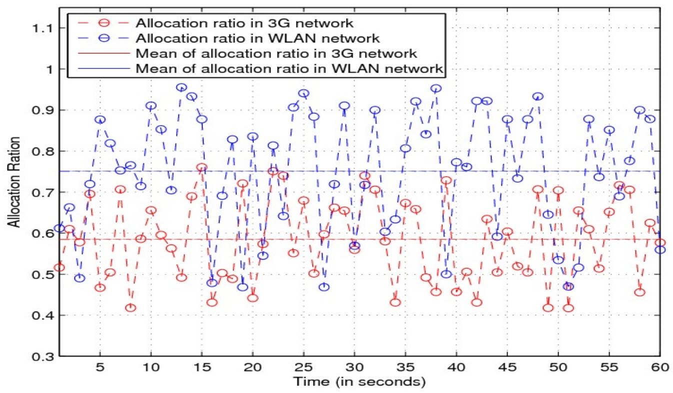

Figure 6: Allocation ratio in 3G and WLAN subnetworks

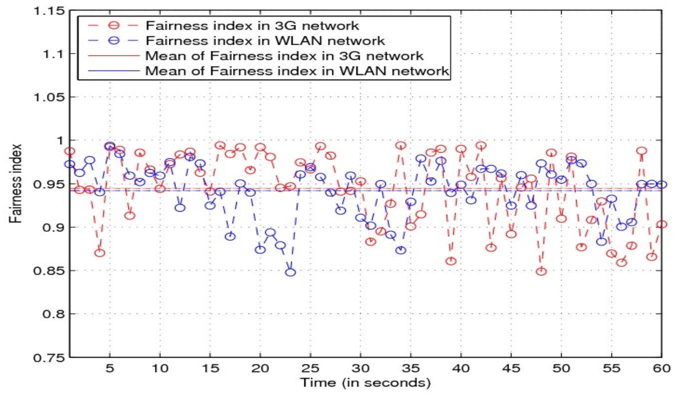

Figure 7: Fairness index in 3G and WLAN subnetworks

resource allocated with respect to the maximum desired resource for all Unode, and is defined as [31]

$$S_j = \frac{1}{U}\sum_{i=1}^{U}\frac{R_{i,j}}{R_{i,j}(max)}. \tag{16}$$

The fairness index represents how fair the algorithm is, and is defined as

$$Fairness\ index_J = \frac{(\sum_{i=1}^{U} R_{i,j})^2}{U\sum_{i=1}^{U} R_{i,j}^2} \tag{17}$$

It can be noticed that the allocation ratio (most of the time) and the mean allocation ratio of the WLAN are higher than that of 3G because of more the availability of resources.

The variation of mean allocation ratio with the number of Unodes in 3G and WLAN subnetwork is shown in Fig 8. Here also the mean of allocation ratio in WLAN is higher, most of the time, than in 3G subnetwork. Similarly, Fig. 9 shows the variation of mean fairness index with the number of Unodes in 3G and WLAN subnetwork. The plot shows that the fairness index decreases slightly when the number

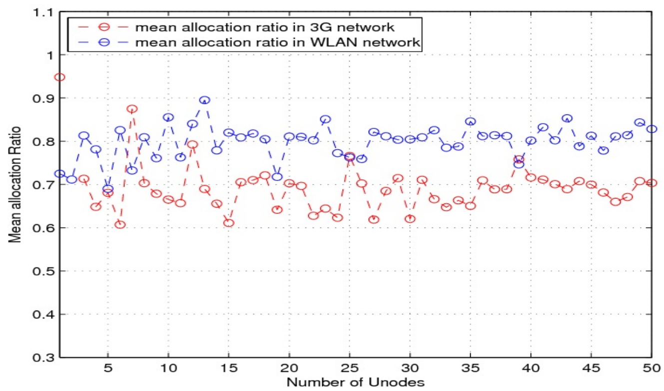

Figure 8: Mean allocation ratio Vs. the number of Unodes

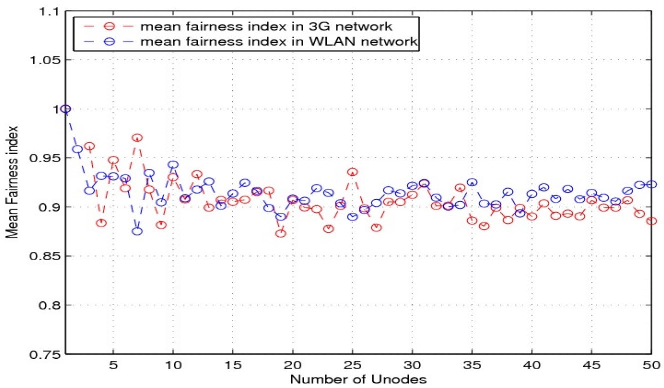

Figure 9: Mean fairness index Vs. the number of Unodes

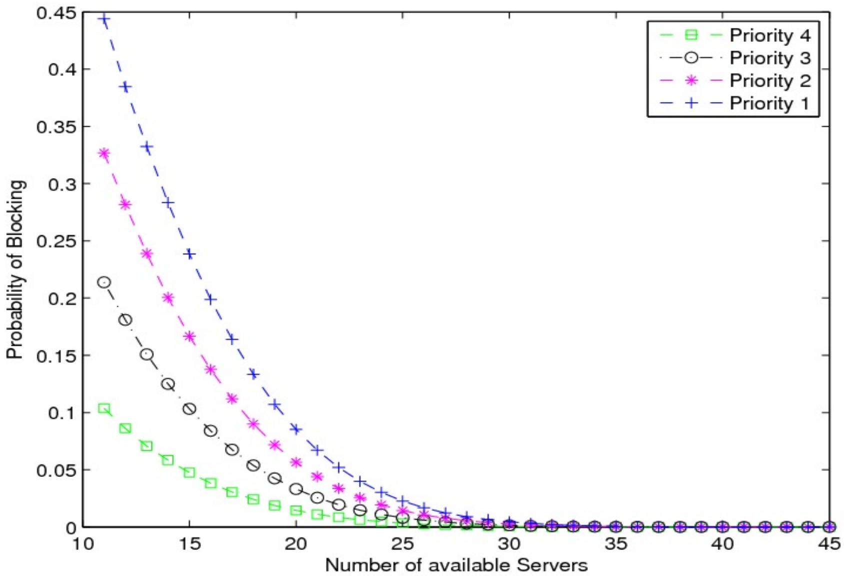

Figure 10: Probability of Blocking versus number of available servers with 4 level of priority

of Unodes increases. Initially the fairness is high as the number of Unodes is high and later it decreases

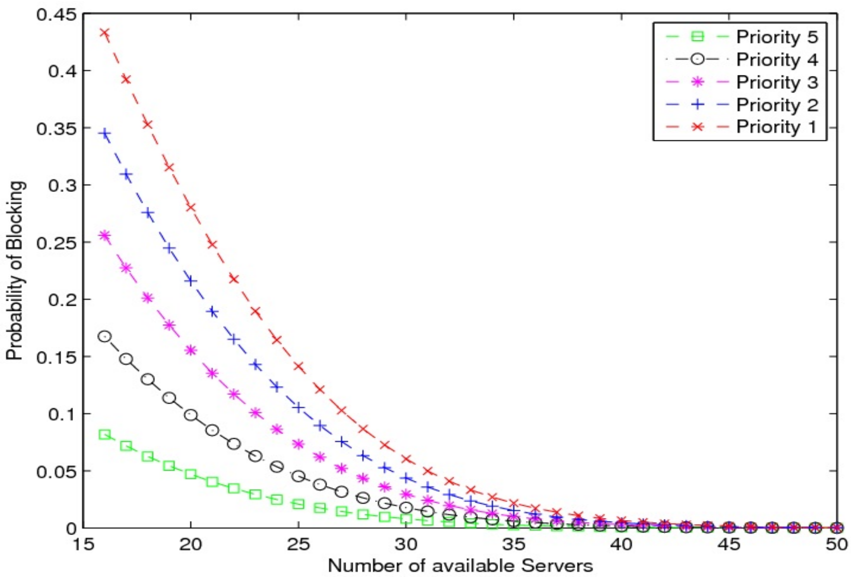

Figure 11: Probability of Blocking versus number of available servers with 5 level of priority

slightly as the number of Unodes increases but the fairness is always greater than 0.85.

The results of analytical modelling are shown in Fig 10 and 11, which show the variation of the blocking probability of Unodes with respect to the available servers. We calculate the blocking probabilities of the Unodes belong to different priority value by considering the number of servers required is equal to the priority value; the mean arrival and service rate as one. We observed as the number of servers increases the blocking probability decreases, as expected, and the probability of blocking is always higher for higher priority Unodes.

9 Conclusion

In this paper, we discussed the resource allocation problem in the ubiquitous network. The designed scheme exploits the advantages of the mobile agents by deploying them in different subnetwork segment to enable the local administration to provide required resources to the unodes, and to ensure the network resources provision by continuously monitoring and taking proactive actions. We have built an analytical model of the proposed resource allocation scheme using queuing concept. The results obtained in the simulation and analysis reflects the effectiveness of the scheme.

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