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SUPPORTING QOS IN NETWORK WITH MOBILE HOST

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Abstract

The current network system architectures and mechanisms to provide real-time applications for fixed hosts are inadequate to accommodate the mobile hosts which can frequently change their point of attachments to the fixed networks. Mobility of host has a significant impact of the QoS parameters of real-time applications. In order to provide QoS to mobile hosts, mobile hosts must first make resource reservations at all locations it may visit during the lifetime of the connection. It is difficult to predict the locations a mobile host will visit in advance. Hence, the resource reserved is often wasted. In this paper, we propose two simple methods, *Linear Equation Based Prediction Scheme* and *Group Based Prediction Scheme*, to predict the locations that a mobile host will visit. We will also propose a new concept called *Link Bandwidth Partition Approach* for bandwidth allocation. Based on this concept, we propose an admission control algorithm for our scheme. Simulation results indicate good flow drop rates

Keywords: Mobile Networks, Quality of Service, Resource Reservation, Admission Control

1. Introduction

In recent years, the technology of wireless communications has made a great progress. Users are not satisfied only with fixed connections but also demand the accessibility of mobility. However, when scientists designed Internet protocols in 1970s, they assumed that hosts are stationary. This means that if we want to support hosts with mobility, we must add or modify the functionality to Internet protocols. To solve this problem, there are many proposals designed [1-4]. The researches, so far, have focused on the problem of maintaining connections for mobile hosts. Figure 1 is the general model of the global architecture to support mobile wireless computing. The model consists of two sets of entities: Mobile Hosts (MHs) and Fixed Hosts. Some of the fixed hosts, called Base Stations (BSs), are augmented with a wireless interface to communicate with mobile hosts. The area that BS can communicate with MHs is called a Cell. Mobile hosts can connect to fixed network through Base Stations.

We know that IP is an unreliable protocol, as it only makes a best effort to deliver data (i.e. IP just provides a simple best-effort service). To support real-time applications in the Internet, Clark et al. [5] have proposed an architecture for an ISPN (Integrated Service Packet Network) that supports real-time applications. The Resource Reservation protocol (RSVP)[6] offers applications just such a reservation service. To support real-time applications with mobile hosts, however, RSVP also needs some modification to adapt to mobility. Talukdar et al. had proposed an MRSVP protocol for supporting QoS in mobile networks.

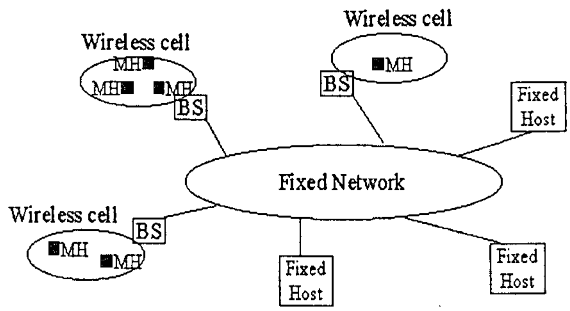

Fig. 1. Model of a system supports mobility.

For supporting QoS in networks with mobile hosts, Talukdar et al. [7-9] extended the service classes described in [5]. They defined three new service classes: MIG (Mobility Independent Guaranteed), MIP (Mobility Independent Predictive) and MDP (Mobility Dependent Predictive).

About the future location movement of MH, the authors of [7-9] assumed that mobility could be characterized precisely by a *mobility specification* which is a set of cells MH is expected to visit during the lifetime of the flow. The assumption is unpractical. In this paper, we propose simple and workable methods to predict the locations where a mobile host may visit, and make resources reservation in advance.

The remainder of the paper is organized as follows. In Section 2, we roughly introduce some related researches in the past. In Section 3, we will propose two methods to predict the movements of the mobile hosts, and a simple admission control algorithm for our scheme. Section 4 will contain the simulation model and simulation results. We conclude in Section 5 with some future research directions of this work.

2. Preliminaries and Related Research

It is very difficult to predict the locations where the mobile hosts will visit and make resource reservation in advance. There are two basic schemes to solve this problem. The first on is termed an *anticipatory reservation scheme* which make resource reservations at all cells surrounding the current cell. Fig. 2 (a) shows this concept (MH is in cell 6, and reserved cells are 2,3,5,7,10 and 11). The advantage of this scheme is simple, but low resource utilization is its disadvantage. The other method is termed a *predictive reservation scheme*. This method makes resource reservation along the most likely path of the mobile user. In theory, *predictive reservation scheme* has high resource utilization. But the utilization will depend on the accuracy of prediction of mobile host movement, which is very difficult.

About mobile computing, maintaining connections for mobile hosts is the focus of [1-4]. They do not discuss the QoS of Mobile Computing. In [5], the authors proposed an architecture supporting real-time applications in an Integrated Service Packet Network (ISPN). This paper mentioned some components of their architecture, such as Service Commitments, Admission Control and Resource Reservation. Later papers [7-9] extended the architecture of [5] to suit the environment of mobile computing. The authors of [7-9] proposed a Resource Reservation Protocol called MRSVP for the mobile environment, and they also proposed admission control algorithms for their architecture. In [11], Singh proposed two new QoS parameters, *Loss profile* and *Probability of seamless communication*, which are unique to the mobile environment. Loss profile is a new QoS parameter, which allows users to specify, during connection setup, a preferred way in which data can be discarded when the bandwidth requirements exceed the available bandwidth. Through specifying this QoS parameter, users can get a graceful degradation of service.

In order to support QoS for the mobile hosts, there should at least exist two components in the network. One is admission control scheme, and the other is reservation scheme. In [12], the authors made comparisons on different admission control schemes. Resource reservation is another component. Resource reservation scheme is a mean to support QoS for special services. The Internet Engineering Task Force (IETF) has defined a Resource Reservation Protocol (RSVP)[6].

3. The Proposed Method

Talukdar et al. assumed that the mobility of a MH is predictable so that mobility can be characterized precisely by a mobility specification. With this assumption, they can make resource reservation in advance in every cell specified in the mobility specification.

They simply assumed that the mobility of the mobile host is predictable, so that they can be characterized by a mobility specification. In the following section, we propose a workable solution for mobility prediction called "*Linear Equation Based Prediction Scheme*". And in Section 3.2 we will introduce our second method called "*Group Based Prediction Scheme*".

3.1 Linear Equation Based Prediction Scheme

The first method is "*Linear Equation Based Prediction Scheme*". We make an assumption first: every BS has a global unique coordinates (x, y) and the cell size and shape is the same. When a mobile host moves to another cell, we will have two coordinates, $(x1, y1)$ and $(x2, y2)$. Thus we have a linear equation through the formula:

$$(x-x1)/(y-y1)=(x1-x2)/(y1-y2) \qquad (1)$$

In figure 2 (b), mobile host moves from cell 6 to cell 10. In cell 10, there are six directions the mobile host can move to next. We assume that 13 will have the highest probability than any other cells. That is, assume a mobile host will move along a straight line, we can make resource reservations in advance, along the straight line locus.

We briefly describe how this method works in the following steps:

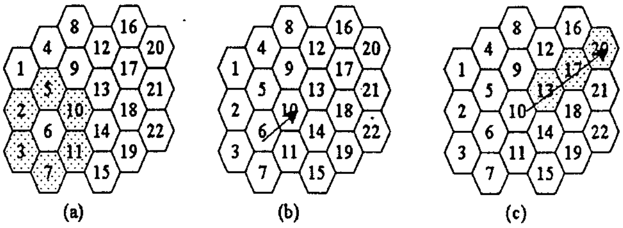

Fig. 2. The "Linear Equation Based Prediction Scheme"

Step 1: When a mobile host turns on its power on a certain cell, and requests real-time service, it will make resource reservation at every cell adjacent to this cell. Figure 2 (a) shows the operation of this step.

Step 2: When MH powers on we can get one coordinate $(x1, y1)$. After MH moves to another cell, we can get another coordinate $(x2, y2)$. Thus we can get a linear equation through (1) as in Fig. 2 (b). We must release the resource that we have reserved in Step 1 except cell 10.

Step 3: Once we have determined the linear equation after a mobile host moves, we can make resource reservation in advance in these cells along the line. In Fig. 2 (c), we make resource reservation in cells 13,17,20. To control the reservation operation, we use two variables: *Cell Counter* and *Reservation Threshold.*

1) Cell Counter: This variable is used to record the information that currently how many cells have resource reserved in advance.

2) Reservation Threshold: When a mobile host leaves a cell, it releases the resource and decreases Cell Counter by *1*. When the value of Cell Counter decreases to Reservation Threshold, the mobile host needs to make resource reservations again.

Step 4: When the mobile host does not follow the direction we expected, we need to release the resource we have reserved. As in Fig. 3, we recalculate the linear equation and make resource reservations again.

The drawback of the *Linear Equation Based Prediction Scheme* is that MH may not always move along the direction of its motion. It may cause flows to be dropped when the MHs do not move along the line. Therefore, we propose another method called "*Group Based Prediction Scheme*" in the following section.

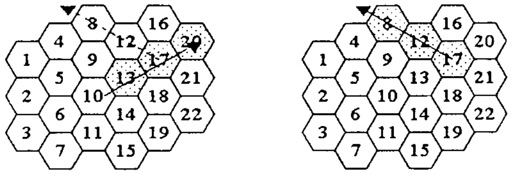

Fig. 3. Release and make resource reservation again.

3.2 Group Based Prediction Scheme

The scheme is based on the concept of group. The cells surrounding the current cell form a group as shows in Fig. 2 (a). When the Mobile Host changes its current cell, the group will change too. We describe our method as follows.

Step 1: When a mobile host turns on its power on a certain cell, it will make resource reservation at every cell adjacent to its current cell. As show in Fig. 4 (a), the MH is in cell 6 and the reservation group is 2,3,5,7,10,11.

Step 2: After the mobile hosts moved, the reservation group is changed. As in Fig. 4 (b), the MH moves to cell 10 and the reservation group is changed to cells 9,13,14. The basic concept of our method is based on the assumption that the probability of a mobile host that moves in a triangular pattern will be greater than any other directions.

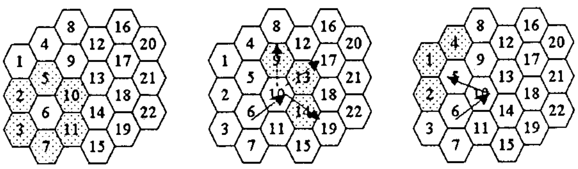

Fig. 4. The Group Based Prediction Scheme.

Step 3: If the movements of the mobile host do not follow the direction we expected (cell 5 instead of cells 9,13,14 in Fig. 4 (b)), we release the resource we have reserved. We re-determine the direction of the motion and make resource reservations again along the direction of movement. Figure 4 (c) shows this operation and the reservation group is 1,2,4.

We can further reduce the group size by considering the physical obstacles, such as a wall, a pond, etc. In a Pico-cell environment, such as a campus network, we can have detailed information about the physical environment to determine whether there is any obstacle between boundaries.

3.3 The Service Commitments

Clark et al. [5] defined two new service classes: *guaranteed* and *predictive* service. Talukdar et al. [7-9] extended these service classes by taking host mobility into account. Thus they defined three new service commitments: MIG (Mobility Independent Guaranteed), MIP (Mobility Independent Predictive) and MDP (Mobility Dependent Predictive). A predictive service is similar to a best effort service. These service commitments are listed in Table 1 and described as follows.

MIG: A mobile user will receive *guaranteed* service with respect to packet delay bounds if its movements are limited to its *mobility specification.*

Service / Mobility	Guaranteed	Predictive
Mobility Independent	MIG	MIP
Mobility Dependent	Not defined	MDP

Table 1. Service commitments proposed by Talukdar et al.

MIP: A mobile user will receive predictive service with respect to packet delay bounds if its movements are limited to its *mobility specification.*

MDP: A mobile user will receive predictive service with high probability in all locations that it may visit during the lifetime of its connection.

Our service commitments are modified from those service commitments of Talkudar et al. [7-9]. In order to concentrate on the validity of our method, we will not support predictive services. Our service commitments are listed in Table 2.

Service / Mobility	Best-Effort	Guaranteed
Mobility Independent	Not defined	P-MIG
Mobility Dependent	Not defined	P-MDP

Table 2. Our service commitments.

Because our method is under the assumption that mobile hosts usually move along the direction of their motion with higher probability, our method could not absolutely guarantee mobility independent service, thus our service commitments are termed P-MIG (Probability-MIG) and P-MDG (Probability-MDG). Here we give definitions to P-MIG service and P-MDG service.

P-MIG: A mobile user will receive guaranteed service with respect to packet delay bounds if its movements follow our prediction scheme.

P-MDG: In this scheme, resource is not reserved in advance. Therefore, when a MH moves to a new cell, the QoS it gets depends on the resource availability of the current cell.

3.4 Admission Control

For admission control, *active flow* and *passive flow* are defined by Talukdar et al. Active flow is the reserved network resource for the flow at the switches or BSs along the data path and these resources are currently used. Passive flow is the reserved network resource for the flow at the switches or BSs along the data path and these resources are not used now. The active flow can borrow the passive flow's bandwidth. Our admission control uses the same concept but is more delicate and elegant. It has two features: 1) there is an upper bound for those passive reservations, 2) there is an upper bound for total bandwidth of passive flows that can be borrowed.

We propose a concept called "*Link Bandwidth Partition Approach*". We divide the bandwidth into four partitions as in Figure 5. The sizes of P1, P2, P3 and P4 are tunable.

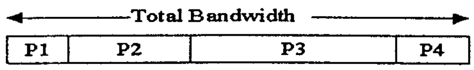

Fig. 5. The overview of Link Bandwidth Partition Approach.

P1 (Partition 1): This partition is used to keep some portion of the bandwidth unreserved. This unreserved bandwidth can be used by the best-effort service.
P2 (Partition 2): This partition is used for those passive flows, such as P-MIG.
P3 (Partition 3): This partition is used for active flows, including P-MIG and P-MDG service.
P4 (Partition 4): This partition is used for MHs that request P-MIG service commitments but they do not make resource reservation in advance (i.e. the mobile host does not move in the predicted pattern.)

Our Link Bandwidth Partition Concept is mainly designed for P2 and P4. In the following, we explain some design principles for our admission control algorithm.
1) Bandwidth Borrowing: For increasing the bandwidth utilization, our admission control algorithm allows P3 to borrow bandwidth from P2. Of course, when some new flows request from P2, and currently P2 does not have enough bandwidth for it, P3 has to return those borrowed bandwidth.
2) Replacement Algorithm: When the bandwidth of P4 overflows, and there are no available bandwidths in other partitions. We can reject this flow, thus cause the hand-off failure; or accept this flow, and it will lead to QoS degradation. And we must select some flows within P4 as victims. There are many alternates for this algorithm. For example, FIFO (First In First Out), LRU (Least Recently Used), etc.

The functionality of any admission control algorithm is to make sure that admittance of a new flow into the network does not violate service commitments made by the network for previous flows. We use a very simple admission control algorithm, called Simple Sum [12]. Furthermore, we allow a new active flow to temporarily borrow bandwidth from those passive flows when there are not enough bandwidth for this request. We also set up an upper bound for passive reservations. This could prevent most of the bandwidths from being reserved for passive flows. Fig. 6 is our admission control function. The parameters are defined as follows.
P3_A : A variable used to store the information about the available bandwidth of P3.
P2_B : A variable used to store the information about the total bandwidth borrowed from P2.
P2_A : A variable used to store the information about the available bandwidth of P2.
μ *:* The total link bandwidth.
ε *:* The percentage of P2.
ρ *:* The upper bound for P2 bandwidth that can be borrowed.

```
Function Admission_Control{
  CASE of Active_Reservation{
    CASE of P_MIG{
      IF P3_A>Request_Bandwidth{Admission_Control:=TRUE;}   /* Accept new flow*/
      ELSE{Admission_Control:=FALSE;}   /*Reject new flow*/
    }
    CASE of P_MDG{
      IF P3_A>Request_Bandwidth{Admission_Control:=TRUE;}   /* Accept new flow*/
      ELSE{
        IF (P2_B<ρ*ε*μ) and ((ρ*ε*μ-P2_B)>Request_Bandwidth){
          Admission_Control:=TRUE;}   /* Accept new flow*/
        ELSE{Admission_Control:=FALSE;}   /*Reject new flow*/
      }
    }
  }
  CASE of Passive_Reservation{
    IF P2_A>Request_Bandwidth {Admission_Control:=TRUE;}   /* Accept the reservation*/
    ELSE{Admission_Control:=FALSE;}   /*Reject the reservation*/
  }
}
```

Fig. 6. The admission control function.

The parameter ρ is used to specify how many bandwidth of P2 that can be borrowed for P-MDG flows. In our *Group Based Prediction Scheme*, we at most make resource reservations in three cells in the current group. This means that when there is a passive flow exists in a Base Station, the probability that this passive flow will become active is 1/3. For increasing the bandwidth utilization, the value of ρ could be 2/3.

4. Simulations Results

The main purpose of our simulations is to show that *the Group Based Prediction Scheme* and our admission control algorithm can provide an acceptable performance to predict the locations where mobile hosts may move and guarantee the QoS they request. The network topology in our simulation is shown in Figure 7. In this figure, there are 33 cells. To simplify the complexity of our simulation, we made some assumptions here.
1) Each Base Station has enough information to determine its neighboring cells.
2) Every flow originates from Service Provider.
3) he bandwidths in the fixed network are infinite.

The main purpose of our simulations is to measure two parameters: link utilization and flow drop rate. There are two types of flow drop rate: P-MIG flow drop Rate and P-MDG flow drop Rate. They are defined as follows:
1) *P-MIG Flow Drop Rate* = (# P-MIG flows dropped) / (# P-MIG admitted into the network)

2) *P-MDG Flow Drop Rate* = (# P-MDG flows dropped) /(# P-MDG admitted into the network)

In our simulations, we will perform three experiments.

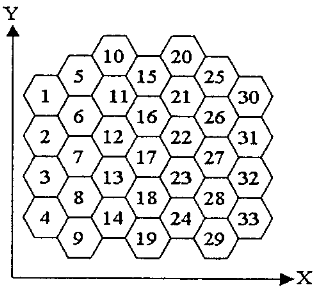

Fig. 7. The cell network topology.

We will choose the values of different parameters listed in Table 3. First, we list the notation of all parameters and their values in our simulations:

λ_a: Mean flow arrival rate in number of flows per minute.

λ_s: Mean stay time of mobile hosts in a cell.

P_m: The probability that a MH moves in the predicted direction.

P-MIG_arrival_rate: The fraction of the arriving flows belonging to the P-MIG service (denoted as **A** in Table 3).

P-MDG_arrival_rate: The fraction of the arriving flows belonging to the P-MDG service (denoted as **B** in Table 3).

P_MIG_arrival_rate + *P_MDG_arrival_rate* = 1 must be satisfied.

ρ : The upper bound of bandwidth that P2 can be borrowed

ε: The percentage of P2

γ: The percentage of P3

ϕ: The percentage of P4

We will perform three experiments. Table 3 lists the parameters of these experiments.

	A	B	λ_s	ρ	ε	γ	φ
Experiment 1	0.5	0.5	5	0.5	0.4	0.5	0.1
Experiment 2	.666	.333	5	0.5	0.4	0.5	0.1
Experiment 3	0.5	0.5	5	0.5	0.4	0.55	0.05

Table 3. Experiment Parameters.

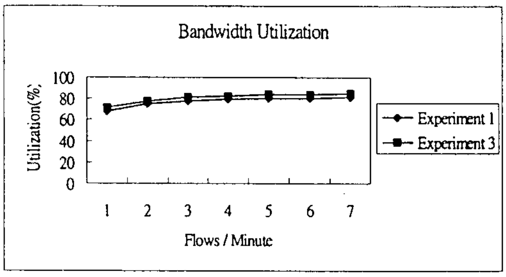

Fig. 8. Utilization vs. Flow arrival rate.

Figure 8 shows the average utilization of Experiment 1 and Experiment 3. The only difference between Experiment 1 and Experiment 3 is the ratio of P3 and P4. From the definition of link utilization, we know that the link utilization is mainly dominated by active flows. And the amount of active flows is determined by the total bandwidth of P3. This means the higher ratio of P3 has the higher bandwidth utilization.

Figure 9 and Figure 10 show the P-MIG flows drop rate under Experiment 1 and Experiment 3. The parameters ϕ and P_m will dominate the value of P-MIG flow drop rate. It is obvious that the P-MIG flow drop rate of Figure 10 is higher than Figure 9. This is because that the value of ϕ in Experiment 3 is smaller than the value of ϕ in Experiment 1.

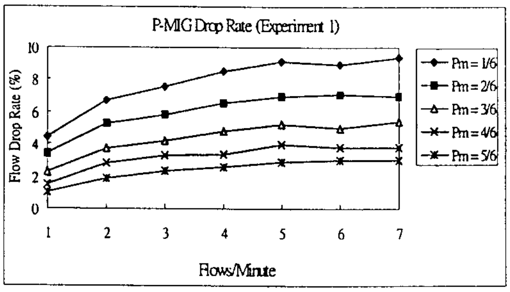

Fig. 9. P-MIG flow drop rate (Experiment 1) vs. Flow arrival rate.

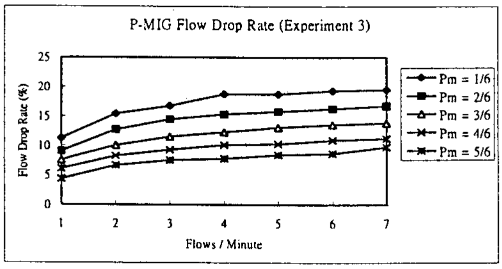

Fig. 10. P-MIG flow drop rate (Experiment 3) vs. Flow arrival rate.

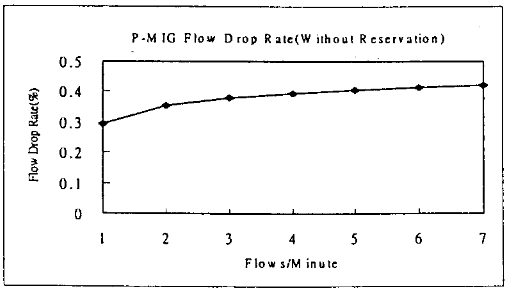

Fig. 11. P-MIG Flow Drop Rate (without reservation).

Figure 11 shows the P-MIG flow drop rate under the case that MHs do not make resource reservation in advance. When the flow arrival rate is 1 flow per minute, the P-MIG flow drop rate is about 30%. When the flow arrival rate is 7 flows per minute, the P-MIG flow drop rate is about 42%. The P-MIG flow drop rate is too high for the mobile hosts to accept.

Figure 12 and Figure 13 show the P-MDG flows drop rate under the Experiment 1 and Experiment 2. In order to achieve higher bandwidth utilization, we allow P-MDG flows to temporarily borrow bandwidth from those passive flows. For decreasing the P-MDG flows drop rate, we set an upper bound for the P-MDG flows that can borrow. From this figure, we show that our method achieves very low P-MDG flows drop rate. In Figure 12 or Figure 13, we could find the fact that the higher P_m, the higher P-MDG drop rate. This is because we allow some P-MDG flows to borrow bandwidth from passive flows in P2. Higher P_m means that the probability that passive flows become active flows is also higher. Thus the P-MDG flows drop rate would arise.

From our simulation results we find that the P-MDG flow drop rate is very low, usually below 1%. The P-MIG flow drop rate is about 9.3%. When P_m is 3/6 and flows arrival rate is 7 flows per minute, the P-MIG flow drop rate is about 5.4%.

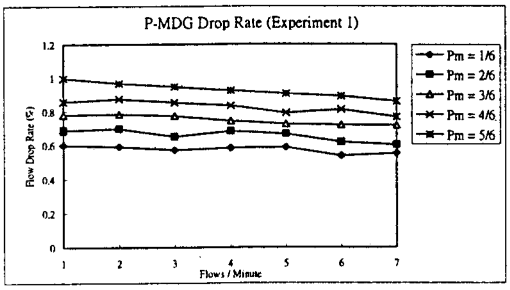

Fig. 12. P-MDG flow drop rate (Experiment 1) vs. Flow arrival rate.

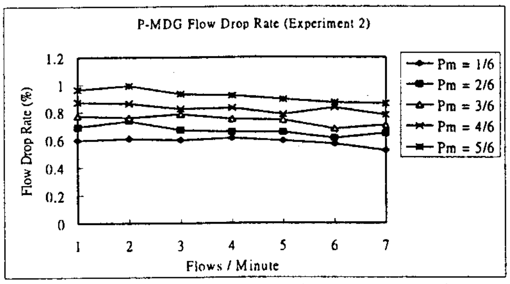

Fig. 13. P-MDG flow drop rate (Experiment 2) vs. Flow arrival rate.

5. Conclusions and Future Work

In this paper, we propose a workable solution for supporting QoS in a mobile network environment. Our method is based on the concept of *linear or group-based prdeiction*. If we have enough information about the physical environment, such as a wall or a pond between two adjacent cells, we can take this information into account while make resource reservations.

Our method can not absolutely guarantee that QoS parameters will always be met. This is because our method is based on the assumption that the probability of mobile host moves in a predicted direction will be greater than other directions. When it is wrong, QoS might be violated. For this situation, we propose one solution to handle it. But in the worst case, the QoS parameters can not be met. We also propose a concept, called "*Link Bandwidth Partition Approach*", for bandwidth allocation. Simulation results show that our scheme can achieve acceptable resource utilization and flows drop rate.

We do not mention how to determine the parameters,ν、ε、γ and ϕ. And our admission control algorithm only considers the bandwidth requirement, without considering the delay requirement. For the real-time applications, delay is a very important consideration. In the future, we can take these parameters into consideration.

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