and communication networks will make possible that users at high speed are able to access the Internet with high data rate. One of the most challenging issues in the Integrated Communication and Broadcast Networks(ICBN) is the feedback information. This can be solved by using a third medium as the uplink for user requests and acknowledgement signaling. Most other access systems like GSM, WCDMA can be used for this purpose.

Quite a huge part of the Internet services like information or software download are one way. ICBN is convenient and cost-effective for distributing Internet resources to users, especially those sharing common interests like traffic reports, tourist information, and so forth. Since the broadcast packets are usually in bursts and in a big traffic volume and may also has diverse QoS requirements, dynamic resource allocation schemes with QoS assurance are crucial. The allocation of the access bandwidth has been carefully designed recently. [3] gives a rate control coding mechanism for DTV, while [2] designs a rate schedule method for IP data transmissions. Both of them work exclusively for either DTV or IP services. [4] makes some improvement and presents a single channel allocation algorithm for transmissions combining DTV and IP traffic. These algorithms work well sometimes. But they are lack of the capability to provide QoS differentiated services to users with different priorities. Besides, their algorithms are fit only for single channel bandwidth scheduling. Considering the combination of DVB-T and Internet as an instance, this paper proposes a multichannel architecture of ICBN to provide enormous access bandwidth. Based on this architecture, a novel approach with low complexity is presented for bandwidth allocation with QoS differentiation to maximize resource utilization profit.

## 2 Design of ICBN with Multiple Channels

Originally, one analog TV program occupies the whole 8 MHz channel. By transmitting digital signals, several DTV programs can be multiplexed in one channel, which greatly improves the capacity of TV programs, and it is possible that too much room exists for DTV programs and redundant channels can be exploited for additional data services. Besides, the transmission robustness has also been greatly enhanced. In DVB-T, mobile reception of signals depends on the geographical environment and the robustness of modes(coding, modulation, etc.) used. For mobile reception, QPSK/16 QAM modulation and ”2k” mode(1075 subcarriers) COFDM modulator will guarantee the required robustness([5]). Based on the physical layer mode, the transmission data rate is constant. In order to get a fixed data rate, e.g. 38Mbit/s per 8 MHz channel, stuffing packets are inserted. These stuffing packets can be exploited for additional data transmission services.

Traditional researches have considered the situation that each DVB channel supplies additional data services separately, and many single channel bandwidth management policies have been designed([3], [2],[4]). However, in each DVB channel, the compression of video and audio data causes a variable data rate, since pictures with fierce motions will be encoded with higher data rate than those with less motions. So the available bandwidth for additional data services varies from time to time. The available resources dynamically distribute in all DVB channels, which can be called channel diversity. Besides, the bandwidth requests of users vary from time to time, which can be called the user diversity. Users that can not be satisfied by one channel may get the required bandwidth from other channels. The effective exploitation of both channel diversity and user diversity will make full use of all DVB resources, and greatly improve system performance. So we propose a multichannel ICBN architecture which combines DVB-T and communication network to provide broadband access services to users with high mobility. The radio station in ICBN would decide the allocation of DVB-T multi-channel resources to each IP stream according to user QoS requirement. In one DVB channel, only limited bandwidth is available for additional data services, and if only one channel is exploited, the application would be very limited. However, the frequency band for broadcast is large and there are dozens of DVB channels. If many or even all the DVB channels are exploited for Internet access services, that would result in huge wireless access bandwidth in each cell, especially when some DVB channels are fully used for additional data services. The joint management of all the channels' bandwidth available for data transmissions would further improve the system throughput. In the following part, we'll model the problem of multichannel bandwidth allocation in ICBN, and give an efficient algorithm to achieve near-global-optimal allocation result for system profit maximization and QoS differentiation.

## 3 Multichannel Scheduling Modeling and Profit Oriented Bandwidth Allocation Optimization

### 3.1 Problem Modeling

$M$ channels are used for additional data services. At the allocating time, $K$ users apply for Internet accesses. Assume that user terminals can receive signal of only one channel(for terminals that support multichannel signal receiving, they can be treated as multi-users, each of which competes for access independently). Besides, all users will either be rejected for lack of sufficient bandwidth or be accepted with supply of full bandwidth. Define:

$$\mathcal{D} = \begin{pmatrix} D_{11} & D_{12} & \dots & D_{1M} \\ D_{21} & D_{22} & \dots & D_{2M} \\ \vdots & \vdots & \ddots & \dots \\ D_{K1} & D_{K2} & \dots & D_{KM} \end{pmatrix}^T, \tag{1}$$

where $D_{ij} = 1$ means user $i$ is included in channel $j$ while $D_{ij} = 0$ otherwise. User $i$ requests $B_i$ bandwidth, and pays $C_i$ for unit bandwidth. Our purpose is to maximize the profit the system earns through the allocation:

$$\begin{aligned} &\max Profit = \max\{\sum_{i=1}^{K}\sum_{j=1}^{M} B_i C_i D_{ij}\}, \\ &s.t. \begin{cases} D_{ij} \in \{0,1\},\ i = 1,\dots,K, j = 1\dots M \\ \sum_{j=1}^{M} D_{ij} \le 1, i = 1,\dots,K, \\ 0 \le \sum_{i=1}^{K} B_i D_{ij} \le R_j,\ j = 1,\dots,M. \end{cases}, \end{aligned} \tag{2}$$

where $R_j$ is the bandwidth for additional data services in channel $j$. The second constraint shows that data for one user can only be transmitted in one channel. Assume

$$(a). \max_{i=1,\dots,K} B_i \le \max_{j=1,\dots,M} R_j, (b). \min_{j=1,\dots,M} R_j \ge \min_{i=1,\dots,K} B_i, (c). \sum_{i=1}^{K} B_i \ge \max_{j=1,\dots,M} R_j$$

to avoid trivial cases. (a) ensures user $i$ can be satisfied at least by one channel as otherwise it may be removed. If (b) is violated, the channel with the smallest available bandwidth may be discounted as no user can be satisfied by it. (c) avoids a trivial solution where all users can be satisfied by the channel with the largest capacity.

This program is found to be a typical 0/1 Multiple Knapsack Problem(MKP), which is NP-complete([6]) with exponential time bounds($\mathcal{O}(2^{KM})$ in our problem). Exact search algorithms like branch-and-bound algorithms([7],[8]) that lead to globally optimal solutions are too time-consuming and can only be applied to very small problems. Recent algorithms based on metaheuristics have been developed to obtain competitive results on larger instances($K = 300, M = 25$), e.g. simulated annealing([9]) and genetic algorithms([10],[11]). However, these methods must run sufficient iterations to get satisfying results, hence they must work off-line and are not feasible for real-time applications. However, in our problem, the bandwidth must be allocated on-line, and the problem may be extremely large, e.g. 83 channels while 1000 active users. Hence, an algorithm with low complexity and good performance is needed. In the following subsections, the upper bounds of the problem will be given, and a novel algorithm that supplies near-global-optimal results with low complexity for real-time bandwidth allocations is presented.

### 3.2 Upper Bounds

Relax the first constraint $D_{ij} \in \{0, 1\}$ in (2) to $0 \le D_{ij} \le 1 (i = 1, \ldots, K, j = 1 \ldots M)$. [14] proved that the objective value of an optimal solution to the linear relaxed MKP is the same as that of an optimal solution to the following ordinary 0-1 Knapsack Problem([12]):

$$\max Profit = \max\{\sum_{i=1}^{K} B_i C_i D_i'\},$$
$$s.t. \begin{cases} D_i' \in \{0,1\},\ i = 1, \ldots, K \\ 0 \le \sum_{i=1}^{K} B_i D_i' \le R. \end{cases}, \tag{3}$$

where $D_i' = \sum_{j=1}^{M} D_{ij}$ indicates whether user $i$ is included by any channel, and $R = \sum_{j=1}^{M} R_j$ may be seen as the bandwidth of the united channels. The Dantzig upper bound([16]) of the corresponding 0-1 Knapsack Problems may be used as the objective profit. Assume all users have been reordered: $C_1 \ge C_2 \ge \cdots \ge C_K$. Let $k$ be given by $k = min\{j : \sum_{i=1}^{j} B_i \ge R\}$. The upper bound is given by:

$$U_{profit} = \sum_{i=1}^{k-1} B_i C_i + (R - \sum_{i=1}^{k-1} B_i) C_k. \tag{4}$$

### 3.3 Profit Oriented Bandwidth Allocation Method for Real-time Large Scale Multichannel Bandwidth Allocation

The basic idea is: at any stage, considering the remaining available bandwidth of all channels and the remaining users that have not yet been given the bandwidth, pick out those that will be considered for bandwidth allocation; allocate the available bandwidth among the selected users. This will be carried out repeatedly until either all users have received the requested bandwidth or the terminating condition is satisfied: $\min_{i=1,\ldots,K^{(k)}} B_i > \max_{j=1,\ldots,M^{(k)}} R_j$, where $K^{(k)}$ and $M^{(k)}$ are the numbers of active users and channels at stage $k$.

*A. User Selection Based on Dynamic Programming*

At stage $k$, $M^{(k)}$ channels are available, and $R^{(k)}(i)$ is available in channel $i(i = 1, \cdots, M^{(k)})$. The united channels' bandwidth is $R^{(k)} = \sum_{i=1}^{M^{(k)}} R^{(k)}(i)$. $K^{(k)}$ users wait for bandwidth allocation with request $B_i^{(k)}$ and unit bandwidth cost $C_i^{(k)}$, for $i = 1, \cdots, K^{(k)}$. Define $P_i^{(k)}(r)$ as the value of the optimal solution for problem (3) when the first $i$ users among $K^{(k)}$ users request for a portion of $r$ bandwidth. It is easy to see that the principle of optimality in dynamic programming holds for (3), i.e. $P_i^{(k)}(r) = \max\{P_{i-1}^{(k)}(r), P_{i-1}^{(k)}(r - B_i^{(k)}) + C_i^{(k)} B_i^{(k)}\}$ which can be rewritten in the following forms:

$$\begin{cases} P_0^{(k)}(r) = \begin{cases} 0 & r \geq 0 \\ -\infty & r < 0 \end{cases} \\ P_i^{(k)}(r) = \max\{P_{i-1}^{(k)}(r), \\ \qquad\qquad P_{i-1}^{(k)}(r - B_i^{(k)}) + C_i^{(k)} B_i^{(k)}\} \end{cases} \tag{5}$$

for $i = 1, \cdots, K^{(k)}$, and $0 \leq r \leq R^{(k)}$. The surrogate problem will then be solved by generating $P_1, P_2, \ldots, P_m$ successively. Hence, based on dynamic programming([15]), the method for selecting users is presented as **Algorithm 1**: USERSELECTIONDP.

Algorithm USERSELECTIONDP has time complexity $O(K^{(k)}R^{(k)}/rStep)$, which may be adjusted by the bandwidth searching step *rStep*. The suggested value of *rStep* is the minimum bandwidth requested among all users. Larger values for *rStep* can be used to reduce the time complexity with corresponding compromised performance.

```
Algorithm 1: USERSELECTIONDP(B,C,tr,rStep)
Input:users' bandwidth request vector B and Unit bandwidth cost vector C,total
    bandwidth tr, and bandwidth searching step rStep;
Output:SU,selection of the users,1 selected,0 otherwise
BS=⌊ tr/rStep ⌋; k ← size of B
for i ← 0 to BS do P[0,i]← 0;
for i← 1 to k do { for j← 0 to BS do { r← j*rStep;
    if B[i]<r and B[i]*C[i]+P[i-1,⌊r-B[i]⌋] >P[i-1,j] then
      {P[i,j]← B[i]*C[i]+P[i-1,⌊ r-B[i]⌋]; keep[i,j]← 1;}
    else{P[i,j]←P[i-1,j];keep[i,j]← 0;} } }
j← BS; for i← K downto 1 do {SU[i]← keep[i,j]; j← ⌊(j*rStep-w[i])/rStep⌋; }
return SU;
```

*B. Bandwidth Allocation Among Selected Users*

The bandwidth allocation is designed as Inheritor Survival Competition Allocation Method(ISCAM), and is profit maximization oriented. ISCAM treats each user as a generation, and different allocation policies as different family histories. Every generation consumes a certain resources(bandwidt) at some place(channel) with some cost(unit bandwidth cost*bandwidth). A constant living population size is kept with best effort. For each generation, every member is greedy and will try to have a child at every proper place, after which he will die and the children will compete with other families' children for survival to keep a constant population size. If someone finds no place with plenty resource for the his child, he will keep alive and compete for the survival of the family. The survival principle is profit oriented and is based on the cumulative cost for the family survival.

The selected users are reordered: $\overline{C}_1 \geq \overline{C}_2 \geq \cdots \geq \overline{C}_s$, where $s$ is the number of selected users. This order is also the inherited order from parent to child, and ensures that user with higher cost will be considered first. $\overline{B}_i$ bandwidth is requested by user $i$. The allocation matrix is $\overline{\mathcal{D}}$, with $M$ rows and $s$ columns. The population size is $N$. At the $l$th$(0 \leq l < s)$ generation, denote family $f(1 \leq f \leq N)$ as $\mathfrak{F}_f^{(l)} = \left(P_f^{(l)}, \mathbf{R}_f^{(l)}, \mathbf{H}_f^{(l)}\right) \in \mathbb{S}^{(l)}$ where $P_f^{(l)}$ is the cumulative cost$(P_f^{(l)} = 0$ when $l = 0)$, $\mathbf{R}_f^{(l)}$ is a row vector with size $M$ recording the remaining available bandwidth in every channel, and $\mathbf{H}_f^{(l)} = [H_f^{(l)}(1), \cdots, H_f^{(l)}(l)]$ is a vector with $l$ length keeping the history of the family. $H_f^{(l)}(i)(i = 1, \cdots, l)$ records the channel in which the $i$th generation of the family got the requested bandwidth, and $H_f^{(l)}(j) = 0(1 \leq j \leq l)$ means that the $j$th generation of the family was temporarily interrupted for lack of bandwidth in any channels. The places where the $l+1$th generation of family $f$ could get the requested bandwidth are: $\mathbb{G}_f^{(l)} = \left\{ i \middle| R_f^{(l)}(i) \geq \overline{B}_{l+1}, i = 1, \cdots, M \right\}$, in each of which a new family will be formed to compete for survival with cumulative cost $P'^{(l)}_f = P_f^{(l)} + \overline{C}_{l+1}^{(k)} \overline{B}_{l+1}^{(k)}$. For each new family, the family history will add where the $l+1$th generation member gets the bandwidth: $\mathbf{H}'^{(l)}_f = [\mathbf{H}_f^{(l)}, i](i \in \mathbb{G}_f^{(l)})$. Denote vector $\delta(i) = [0\ 0 \cdots 1 \cdots 0]$, in which the $i$th element is 1. Then the remaining resources of the child family is $\mathbf{R}'^{(l)}_f = \mathbf{R}_f^{(l)} - \delta(i)\overline{B}_{l+1}(i \in \mathbb{G}_f^{(l)})$. If $\mathbb{G}_f^{(l)}$ is an empty set, the present family will keep alive and try to compete for survival with $P'^{(l)}_f = P_f^{(l)}$,$\mathbf{H}'^{(l)}_f = [\mathbf{H}_f^{(l)}, 0]$ and $\mathbf{R}'^{(l)}_f = \mathbf{R}_f^{(l)}$. Define $\varPhi(\mathbb{G}_f^{(l)}) = \begin{cases} 0 \ \mathbb{G}_f^{(l)} \in \emptyset \\ 1 \ otherwise \end{cases}$, The child family set of family $f$ at the $l$th generation will be:

$$\begin{aligned} \mathbb{S}'^{(l)}_f = & \Big\{ \big(P'^{(l)}_f, \mathbf{R}'^{(l)}_f, \mathbf{H}'^{(l)}_f\big) \Big| P'^{(l)}_f = P_f^{(l)} + \overline{C}_{l+1}^{(k)} \overline{B}_{l+1}^{(k)} \varPhi(\mathbb{G}_f^{(l)}), \mathbf{H}'^{(l)}_f = [\mathbf{H}_f^{(l)}, i], \\ & \mathbf{R}'^{(l)}_f = \mathbf{R}_f^{(l)} - \delta(i)\overline{B}_{l+1}, where\ i \in \mathbb{G}_f^{(l)}, i = 0\ when\ \mathbb{G}_f^{(l)} \in \emptyset \Big\} \end{aligned} \tag{6}$$

The candidate family of the $l+1$th generation are:$\mathbb{S}'^{(l)} = \bigcup_{f=1,\cdots,N} \mathbb{S}'^{(l)}_f$, which is the union of child families of the $l$th generation . The size of set $\mathbb{S}^{(l)}$ may be far larger than the population size $N$, and $N$ families in $\mathbb{S}^{(l)}$ should be selected.

A certain survival principle need to be established for the selection. In order to serve our profit maximum objective, families with higher cumulative cost will be picked with priority, and those with equal cost will be selected randomly with equal probability. Divide $\mathbb{S}^{(l)}$ into $u$ subsets: $\mathbb{S}'^{(l)} = \mathbb{S}'_1 \bigcup \mathbb{S}'_2 \bigcup \cdots \bigcup \mathbb{S}'_u$, which satisfies:$\forall i, j, 1 \leq i < j \leq u$,$\forall \mathfrak{F}_1 \in \mathbb{S}'_i, \forall \mathfrak{F}_2 \in \mathbb{S}'_j$, cumulative cost of family $\mathfrak{F}_1$ is bigger than that of $\mathfrak{F}_2$. The selected $l+1$th generation families will be:

$$\mathbb{S}^{(l+1)} = (\mathbb{S}'_1 \bigcup \mathbb{S}'_2 \bigcup \cdots \bigcup \mathbb{S}'_{t-1}) \bigcup \overline{\mathbb{S}}'_t, \tag{7}$$

in which$\left|\mathbb{S}'_1 \bigcup \cdots \bigcup \mathbb{S}'_{t-1}\right| < N \leq \left|\mathbb{S}'_1 \bigcup \cdots \bigcup \mathbb{S}'_t\right|$, and $\overline{\mathbb{S}}'_t$ is a subset of $\mathbb{S}'_t$ randomly chosen so that $\left|\overline{\mathbb{S}}'_t\right| = N - \left|\mathbb{S}'_1 \bigcup \cdots \bigcup \mathbb{S}'_{t-1}\right|$. Here, $|\bullet|$ denotes the size of set $\bullet$.

```
**Algorithm 2: ISCAM**(B,C,R,N)
**Input**:selected users' bandwidth request vector **B** and unit bandwidth cost vector **C**,
    channel bandwidth vector **R**,population size **N**
**Output**:allocation matrix **D**.
**Reorder** so that $\overline{C}_1 \geq \overline{C}_2 \geq \cdots \geq \overline{C}_s$ with $\overline{B}_1, \overline{B}_1, \cdots, \overline{B}_s$, $s$ is size of B;
**Initialize**: $\mathbb{S}^{(0)} = \{(P_f^{(0)} = 0, \mathbf{R}_f^{(0)} = R, \mathbf{H}_f^{(0)} = \emptyset) | f = 1, \cdots, N\}$
**for** l ← 0 **to** s-1 **do** {
  **for** f← 1 **to** N **do** {
      **Child Family Form**: get $\mathbb{S}'^{(l)}_f$ according to (6)}
  **Children Family Survival**: get $\mathbb{S}^{(l+1)}$according to (7)}
**Allocation**:pick the best family and allocate the bandwidth according to(8)
**Restore** the allocation result $\overline{\mathcal{D}}$ to original user order $\mathcal{D}$, and **Return** $\mathcal{D}$;
```

The $l+1$th generation families will go on propagating. The procreation and survival process will continue until all remaining resources(bandwidth) have been used up or the last generation($s$th) families are born. The final allocation scheme is the history of family with the most cumulative cost:

$$\overline{D}_{ij} = \begin{cases} 1 \; i = H_m^{(s)}(j) \\ 0 \; otherwise \end{cases} i = 1, \cdots, M, j = 1, \cdots, s \tag{8}$$

where $\mathbf{H}_m^{(s)} = [H_m^{(s)}(1), \cdots, H_m^{(s)}(s)]$ belongs to family $\mathfrak{F}_m^{(s)}$, and $\forall \mathfrak{F}^{(s)} \in \mathbb{S}^{(s)}$, $P_m^{(s)}$ of $\mathfrak{F}_m^{(s)}$ is no smaller than $P^{(s)}$ of $\mathfrak{F}^{(s)}$.

Algorithm ISCAM is shown in **Algorithm 2** with time complexity $O(sN)$ which can be adjusted by population size $N$.

*C. Profit Oriented Bandwidth Allocation*

The complete Multichannel Profit Oriented Allocation Method (MPOAM) is shown in **Algorithm 3**. MPOAM has time complexity $O(K \cdot r/rStep + KN)$, in which $K$ is user number and $r$ is the united channel bandwidth. Both the searching step $rStep$ and population size $N$ can be adjusted to get a balance between performance and complexity. MPOAM is near global optimal since the user selection operations in MPOAM are based on dynamic programming, which itself has been proved to be global optimal([15]).

```
**Algorithm 3: MPOAM**(B,C,R)
**Input**: bandwidth request vector **B**, unit bandwidth cost vector **C**,channel bandwidth **R**
**Output**:allocation matrix $\mathcal{D}$.
**Initialize**:$rStep, N$, $\mathcal{D} \leftarrow \{\mathbf{0}\}$. Remove users/channels violating (??)/(??) get B',C',R';
**while** B' is not empty **and** R' is not empty **do**{
    tr ← sum of all R' elements; SU ←**USERSELECTIONDP**(B',C',tr,rStep);
    select the users according to SU, and get $\overline{B'}, \overline{C'}$; $\mathcal{D}' \leftarrow$ **ISCAM**($\overline{B'}, \overline{C'}$,R',N);
    **Record** the allocation in $\mathcal{D}$ according to $\mathcal{D}'$ and SU;
    **Remove** the satisfied users and the allocated bandwidth in each channel, then
        remove the remaining users/channels that violate (??)/(??), get B',C',R'; }
**return** $\mathcal{D}$;
```

## 4 Simulation Results and Performance Analysis

For mobile reception, we consider a robust DVB-T mode in the simulations: 16-QAM constellations, "2K mode" COFDM modulator with guard interval $1/4(56\mu s)$, and $r = 1/2$ code rate(data rate 9.95Mbps) in a 7.61MHz UHF channel. One MPEG-2 transport stream is transported for each DTV program, and each stream takes about 4-6Mbps for standard definition television. The high quality digital television program is assumed to be a near CBR stream having Gaussian distributed data rate with mean 6Mbps and variance 100Kbps. Each air channel contains one DTV program. We assume that all user requests are IP content downloading. Besides, for each user, the access requests come as poisson arrival processes with gaussian distributed data rate requirement. The service time is exponentially distributed. Users are classified into five priorities, and the one with priority $P = i$ is assumed to pay $i$ for unit bandwidth.

Consider the joint exploitation of five channels. Thirty active users with uniformly distributed priorities are applying for access services with random data rate requests that have mean value 768Kbps and variance 200Kbps. The mean service time of all users is $1/\lambda = 10s$. Compare the performance of using MPOAM and genetic method([13]). In the genetic method, a maximum of 500 generations is configured, and the terminating condition is the variance of the last 50 fitness value no larger than 0.1. Fig.1 shows the results, which traces the system profit earned for the first 100 allocating time slots. The system profit of both MPOAM and genetic method has been normalized by profit upperbound (4). As shown in Fig.1, MPOAM outperforms the genetic method greatly. On average, MPOAM reaches 95.6% of the profit upperbound, while the genetic method only 82.2%. Besides, during this simulation, the average execution time of MPOAM is only 0.0094/11.52 = 0.08% of the genetic method. And MPOAM is quite competent for on-line joint channel bandwidth allocation.

Fig.2 presents the simulation results in the form of vertical column graph for comparing the joint channel scheduling and separate channel scheduling. The separate channel bandwidth allocation is to fill each channel one by one, while MPOAM is used as the joint channel bandwidth management policy. The simulation scenario is the same with those in Fig.1. The system profit has been traced for the first 40 allocating time slots. At each time slot, three columns, marked by blank, slash and grid rectangles respectively, are plotted to show the system profit earned through separate channel allocation, joint channel allocation and the ideal channel allocation(profit upperbound). As shown in the graph, the joint channel resource management will effectively improve the utilization value as compared with separate channel management. Averagely, MPOAM performs 35.9% better than separate channel scheduling under our simulation scenarios.

Under MPOAM, users with different priorities will receive services with different QoS, which is measured by the successful access rate. Fig.3 gives the simulation result about the QoS differentiation ability of MPOAM. Five air channels are used. The priority of each user is randomly selected between 1 and 5. The probability that the user will succeed in getting the access admission is given, and we simulate over different active user numbers, ranging between 10 and 60. As shown in Fig.3, when the system has light load(10 to 20 active users), most users will get a portion of the access bandwidth. With the increase of active users, those with lower priorities will be rejected for access to give more room for

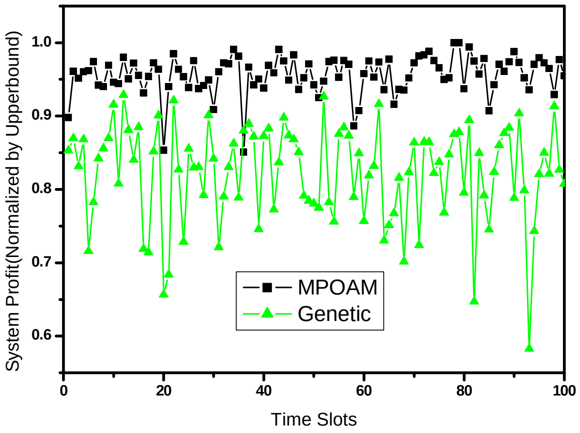

**Fig. 1.** System Profit Comparison between MPOAM and Genetic Method (normalized by upperbound of system profit)

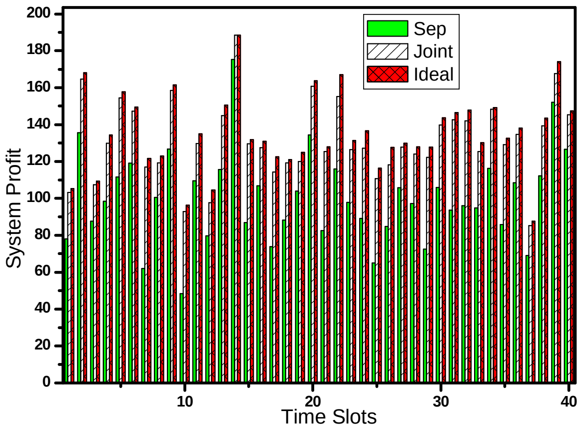

**Fig. 2.** System Profit Comparison between Joint and Separate Channel Management

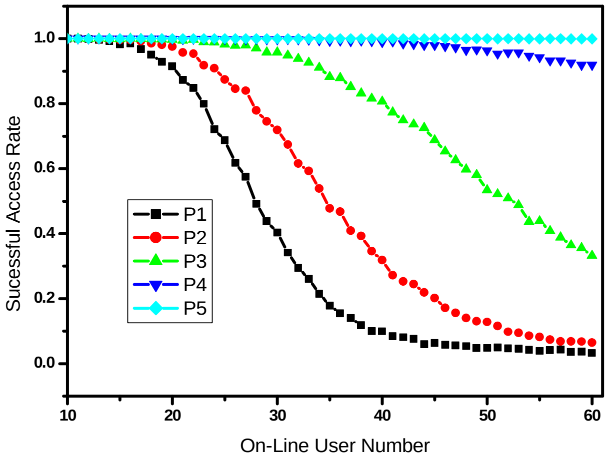

**Fig. 3.** QoS(access rate) Differentiation Provided by MPOAM

users with higher priorities. The users with the highest priority($p = 5$) have always been admitted to access the Internet for this load range. It is proved by the simulation result that effective QoS differentiation has been provided by MPOAM.

## 5 Conclusions and Future Work

In this paper, a multichannel architecture of integrated Internet and DVB-T network has been proposed. The main advantage of the multichannel architecture is that it can provide huge access bandwidth compared with other access technologies, especially if the user terminal supports multi-channel signal receiving and all air channels are exploited for additional IP data transmissions. The robust transmission capability of DVB-T will enable high data rate transmissions to users with high mobility. Hence it can be a highly recommendable candidate of future 4G/5G communications. In order to give effective management of the multichannel resources, MPOAM is presented. The simulation results of MPOAM powerfully show that MPOAM can effectively exploit the broadcast multichannel resources for profit near global maximization, and the joint channel management outperforms the separate channel management greatly. MPOAM can also supply services with effective QoS differentiation according to their QoS level. The complexity of MPOAM is low enough for real time multichannel bandwidth management even when there're dozens of joint channels and hundreds of active users.

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