# An Enhanced Forward-Link Scheduling Algorithm for cdma2000 1x EV-DO

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***Abstract*--cdma2000 1x EV-DO system is originally designed to support high date rate services, but with the development of demand, it is expected to serve some other traffic such as VoIP which belong to conversational QoS class and interactive games. In traditional EV-DO system forward link scheduling, proportional fair (PF) algorithm is used, which doesn't consider QoS like delay and loss, so it can't work when different QoS requirement users are waiting to be served by the same AN(Access Network). To solve this problem, in the latest release of EV-DO specification, a Multi-User packet (MUP) scheme is introduced. Security layer Packets from different ATs (Access Terminal) can be packed into a same MAC layer packet and then be transmitted to the physical layer, however, when should AN use MUP and how to schedule different users to fill this MUP is a problem. A proper scheduling algorithm must be used to optimize system performance. In this paper, we propose a forward link scheduling algorithm supporting the MUP scheme and show performance of EV-DO system under this scheduler.**

***Keywords*--EV-DO, scheduling, proportional fair, delay, Multi-User packet**

## I. INTRODUCTION

The term Third Generation Wireless or 3G is used to define an umbrella of standards and systems for the next generation of mobile systems. Some of the key goals of 3G systems are to build on the success of 2G systems by offering more voice capacity and supporting packet data service such as Internet Access. Some of the services, such as multimedia, require 3G systems to offer data rates in excess of 2Mbps.

Two solutions have been designed for evolution from cdma2000 1x system. They are 1x EV-DO (data only) and 1x EV-DV (data and voice). Complexity of managing and allocating resources for both voice service and data service simultaneously is a great disadvantage of EV-DV system and makes it less competitive. So EV-DO is currently a preferred option for many operators.

EV-DO is originally designed only to serve the non-real time users. In the old release of EV-DO system, fat-pipe scheduling is used to achieve higher data rates. The entire set of forward channels is allocated to a single user and each sector has only one physical channel every slot. It uses time division multiplexing (TDM) for each forward channel. This allows system to support data rates from 38.4kbps to 2.457Mbps in the forward direction. The forward channel structure is as follows:

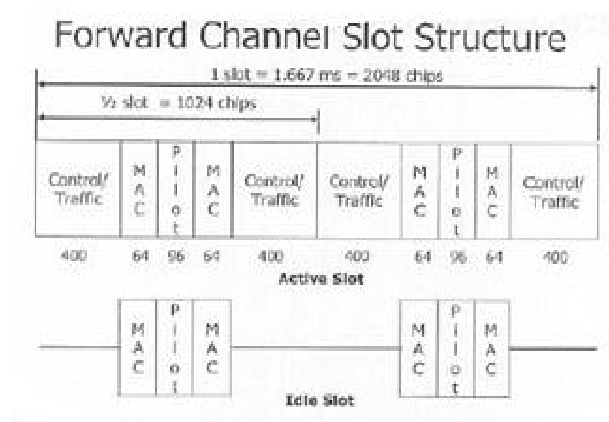


Figure 1 Forward Channel Slot Structure

In recently EV-DO system, it is required to support some real-time traffic such as VoIP and interactive games by introducing a number of optimizations over the air.

Some algorithms have been proposed to solve this problem [6]. In recent version of EV-DO, the Multi-User packet was proposed.

The most significant optimization introduced is Multi-User packet scheme which benefit to reduce the latency of real-time applications and to increase the system throughput by improving efficiency.

AN should schedule all of its ATs using some scheduling algorithm to decide when to use the MUP and which AT or ATs should be served next slot. So we can see that the scheduling algorithm play a most important role in system performance.

There are many scheduling algorithm candidates for EV-DO system such as Round Robin scheduler, PF scheduler and max C/I scheduler and so on[5]. In conventional EV-DO system, proportional fair algorithm is used to guarantee both the fairness and throughput and make a balance between them.

Obviously, in current EV-DO system, PF algorithm, which doesn't take the delay and loss into account, can't satisfy the system requirement anymore. A new scheduling algorithm is needed.

The remainder of the paper is organized as follows. Section II gives a brief overview of the cdma2000 1x EV-DO Release A system and Section III describes the scheduling algorithm we proposed. Section IV provides simulation assumptions and Section V provides results under this new scheduling algorithm. Finally, conclusion is given in Section VI.

## II. SYSTEM DESCRIPTION

According to the latest specification of cdma2000 1x EV-DO, features and working schemes of EV-DO system are as follows[1]:

**First**: there is no soft handoff in EV-DO system, which can reduce the interference levels in the near sectors to improve the system throughput. Each AT continuously measures the forward pilot strength of its active set and chooses a proper sector as its serving sector each slot. Network only transmits on the serving sector selected by AT.

**Second**: AT estimates forward channel conditions of its serving sector every slot by measuring the forward pilot strength. Then, AT maps C/I of forward pilot channel to the transmission format (TF) and then reports this TF to its serving sector in the form of Data Rate Channel (DRC) index. Adaptive modulation and coding are adopted here, because different transmission formats are corresponding to different modulation and coding scheme.

**Third**: AN decides whether to use a single user packet or a MUP considering the traffics QoS, scheduling history and channel conditions and then selects AT/ATs who will be served in next slot and the transmission format it will used in next slot using some special scheduling algorithm, and then transmits the traffic to the specified AT/ATs in the max power and using all of 16 Walsh codes. In this step, different scheduling strategies impact the system performance significantly. Table 1 shows the optional TF for EV-DO RevA. The components of AN are defined as (Physical layer payload, Nominal Transmission duration, Preamble length).We can see from that there are two kinds of TFs according to each DRC index. If AN chooses single user packet, to each DRC index, there are also several compatible TFs. In Table 1, we only give the one with the max payload. There are eight TFs for MUP. For each DRC index, it can support all of the TFs whose payload is less or equal than the one listed in Table 1.

**Forth:** EV-DO adopts the HARQ scheme for fast retransmission and low physical layer packet error rate. At receiver, it combined the retransmission symbol with the previously received ones if a retransmission is required. The transmission of HARQ packet is 4 slots interlacing which means the retransmission packet can only be send 4 slots later after the last transmission. So the 4-slots interlacing HARQ can exploits both the time diversity gain and coding gain.

Figure 2 shows the system model based on the system described above.

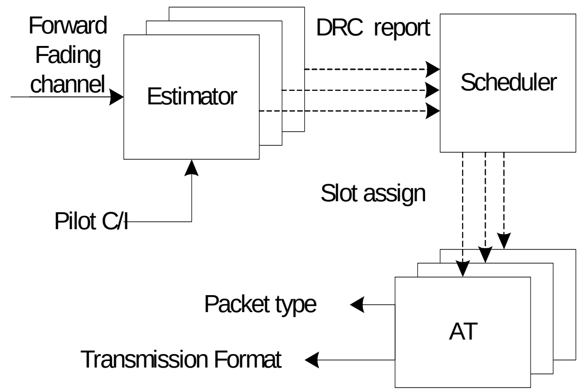


Figure 2 System Model

| DRC index | Single user canonical Transmission Format | Multi user Transmission Format with max payload |
|---|---|---|
| 0x0 | (1024,16,1024) | N/A |
| 0x1 | (1024,16,1024) | N/A |
| 0x2 | (1024,8,512) | N/A |
| 0x3 | (1024,4,256) | (1024,4,256) |
| 0x4 | (1024,2,128) | (1024,4,256) |
| 0x5 | (2048,4,128) | (2048,4,128) |
| 0x6 | (1024,1,64) | (1024,4,256) |
| 0x7 | (2048,2,64) | (2048,4,128) |
| 0x8 | (3072,2,64) | (3072,2,64) |
| 0x9 | (2048,1,64) | (2048,4,128) |
| 0xA | (4096,2,64) | (4096,2,64) |
| 0xB | (3072,1,64) | (3072,2,64) |
| 0xC | (4096,1,64) | (4096,2,64) |
| 0xD | (5120,2,64) | (5120,2,64) |
| 0xE | (5120,1,64) | (5120,2,64) |

Table 1 Transmission formats

## III. SCHEDULING ALGORITHM

### *A. Proportional fair Algorithm*

One of the proposed algorithms for early EV-DO system is proportional fair scheduling algorithm [3]. The principle of the PF algorithm is to schedule users for transmission with a best priority. In EV-DO system this priority is defined to the current DRC value-to-average data rate ratio, which is an IIR filter value. Below is the expression of priority of AT i in slot n:

$$P_i(n)=DRC_i(n)/R_i(n) \qquad (1)$$

$$R_i(n)=(1-1/T)*R_i(n-1)+1/T*DRC_i^{assgned}(n)$$

*where T is the time constant of DRC filter*
*If in slot n AT is not allocated resource*
*$DRC_i^{assgned}(n)$ is set to zero*

In order to take benefit of the Multi-User diversity, PF algorithm is intended to select users who have the largest "changing" in RF conditions this slot. So PF algorithm only considers the current and past channel conditions and cannot directly be adopted to schedule both real-time and non-real time traffic simultaneously.

### B. Scheduling algorithm for Multi-User packets scheme

Considering the cooperation of single user packet and Multi-User packet, we proposed a "two-layer" scheduling algorithm for AN forward link scheduling.

**First layer:**

**First:**

After receiving DRC report from every AT in reverse link, AN should use PF algorithm to calculate the priority $P_i$ according to equation (1) for each AT and select a prior AT to serve.

**Second:**

Usually, a DRC index is corresponding to a set of compatible transmission formats. For example, for DRC index 3, formats (128, 4, 256), (256, 4, 256), (512, 4, 256), ***(1024, 4, 256)*** are compatible with it. Among the transmission formats associated with a DRC index, the TF with the largest physical layer packet size is defined to be the canonical TF of this DRC index. Here the canonical TF is typed in bold italic. AN will firstly use the canonical TF as the preferred transmission format. Then AN should check the buffer size $B_i$ of this prior AT. There are two cases according to relation between $B_i$ and current physical layer packet size $PS_{can.}$ The $PS_{can}$ is the packet size of the canonical format.

$$\begin{cases} \text{Transmit a single user packet} & Bi >= PS_{can} \text{ or not C1} \\ \text{Transmit a multi-user packet} & Bi < PS_{can} \&\& C1 \end{cases}$$

*C1: DRC index of this user support the Multi-User packet*

**Second layer:**

**First**: AN classifies the ATs into delay-sensitive category and bandwidth-sensitive category according to their traffic QoS.

**Second**: AN sorts these two categories based on different criterions. For the delay-sensitive users, AN considers the time waiting to be scheduled at first. Then AN prefers to select the AT who has good channel condition or larger DRC index. At last, AN takes the buffer size into account. AT who has a smaller buffer size will get the higher priority.

For the bandwidth-sensitive users, AN will give AT who has a larger DRC index a higher priority to guarantee the throughput. Waiting time and buffer size are the secondary and tertiary factors. All of the following algorithms are based on these sorted lists. We can call these two lists: D-List and B-List, which denote delay-sensitive list and bandwidth-sensitive list separately.

**Third:** D-list has higher priority than B-List. Orderly searches for next AT to be served in D-list first and then B-list.

AN does scheduling as follows:

Here we introduce two sets: User Set and TF set. User Set contains ATs, which is to be served. TF set contains TFs that all of the ATs in User Set can support. TotalSize denotes the total traffic to be transmitted in next slot.

```
User1 = user selected by first layer scheduling;
Initialize TF Set = TFs that User1 can support according
to its DRC index;
Push User1 into User Set
Initialize TotalSize = buffer size of User1;
WHILE
(Size of User Set < max number of allowed user in MUP
&& TotalSize < packet size of TF, which has the largest
packet size in TF Set)
{
    NextUser = next user whose buffer is not empty in D-
    list first and B-list later;
    TempSet = intersection of current TF set and
    supported TF Set Of NextUser;
    IF (packet size of TF which has the largest packet
    size in TempSet < TotalSize)
   {
        Continue to select next user and maintain current
        TF set unchanged;
    }
    ELSE
    {
        Set current TF Set = TempSet;
         TotalSize = TotalSize + buffer size of NextUser;
         TotalSize = min (TotalSize, packet size of TF
          which has the largest packet size in current TF
          Set);
         Push NextUser into User Set;
    }
  }
```

**Forth:** AN checks the size of user set. If the size is equal to 1, that means no proper users in D-list and B-list has data to transmit. Then AN should adjust current TF to the TF which has the smallest physical layer packet size that can carry the traffic of User we selected in first layer scheduling and change to transmit a single user packet. If there are more than one user in User Set, go to step 5.

**Fifth:** AN chooses the TF which can accommodate the TotalSize traffic we got in step 3 in current TF Set and transmits a Multi-User packet using this TF.

Figure 5and

Figure 6 layer 2 scheduling algorithm shows the flow chart of detailed layer 1 and layer 2 scheduling algorithm:

## IV. SIMULATION ASSUMPTION

In this section we present the simulation assumption. In the simulations, a 21-sector network layout with 7 BTSs is employed. To avoid edge effects, the "wrap-around" feature is used.

The distribution of VoIP service users [4] and FTP service users [2] is as follows:

| User service | percentage |
|---|---|
| VoIP | 70% |
| FTP | 30% |

Table 2 service distribution

All of the simulation is based on a cdma2000 1X EV-DO dynamic system level simulation platform including most of the RRM algorithms.

| | |
|---|---|
| Cell Configuration | 21-sector with Wrap-around |
| Log-Normal Shadowing | std = 8.0 dB, Base Station Correlation = 0.5 |
| Maximum path loss | 157 dB |
| Maximum BTS Tx. Power | 20 W |
| SAW number | 4 |
| Channel Model | Model A [2], 3km/h, 2 figure, PA |
| RAKE Finger Combining | MRC |
| Small-scale Fading | JTC Fader |
| Total simulation time | 300 sec (180000 slots) |

Table 3 parameters setting of simulation

## V. SIMULATION RESULTS

In the section, to evaluate the performances of our proposed new algorithm, we compared them with conventional proportional fair scheduling which does not give priority to VoIP packets.

Figure 3 shows the throughput with these two algorithms.

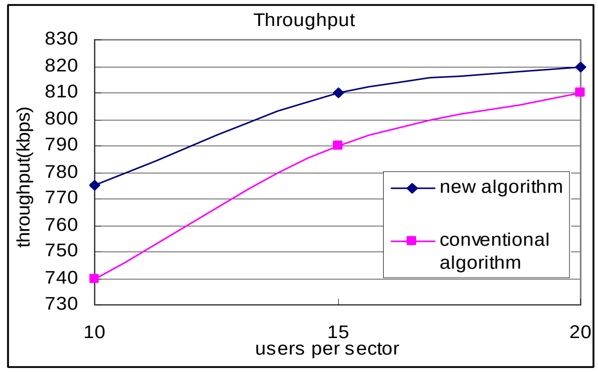


Figure 3 Throughput compare

It is obvious that by adapting the new algorithm, the throughput increase is achieved. Because the new algorithm can take more advantage of the channel condition variation and can give a "lift" to VoIP users.

Figure 4 shows the loss of VoIP users with these two algorithms.

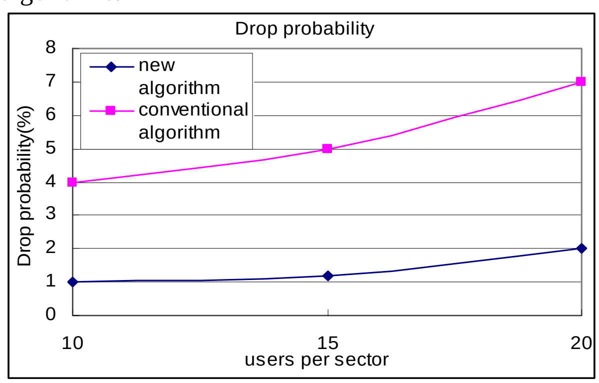


Figure 4 Drop Probability

The main advantage of the new algorithm over the conventional one is the decreasing of the drop probability of the VoIP users. Because VoIP users always required less bandwidth, if the scheduled user has some vacancy, it can take several VoIP users less than 8 which is a limit of MUP. It can be seen from Figure 3 and Figure 4 that the new algorithm can improve the VoIP users' performance without impacting the performance of the FTP users or the entire system performance.

## VI. CONCLUSION

The requirement of supporting some real-time traffic such as VoIP and interactive games in EV-DO systems challenges the traditional EV-DO systems. Some algorithms are introduced to solve this problem. Proportional fair is the most common one. But it is sometimes more suit for the elastic traffic such as web browsing, FTP, email and so on.

In this paper, we proposed a new “two layer” scheduling algorithm which can give a lift to users if possible whose QoS is more preferred on delay and loss.

We compare the performance of this new algorithm and the traditional proportional fair algorithm. The results demonstrate that this new algorithm can achieve noticeable better performance and can satisfy more real time traffic users without the sacrifice of elastic traffic users.

However, how to improve all of the users performance is left to a future work and need further study.

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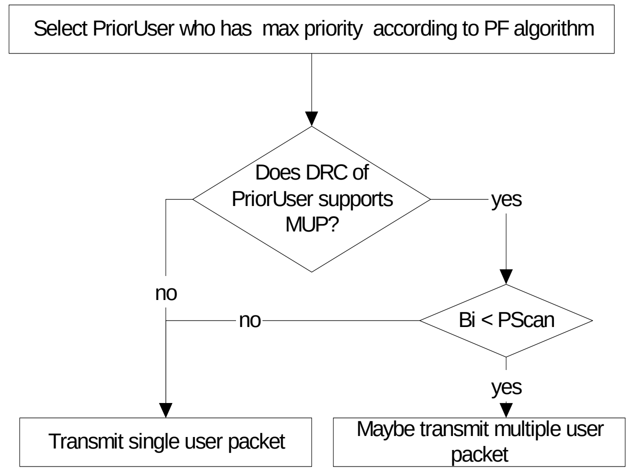
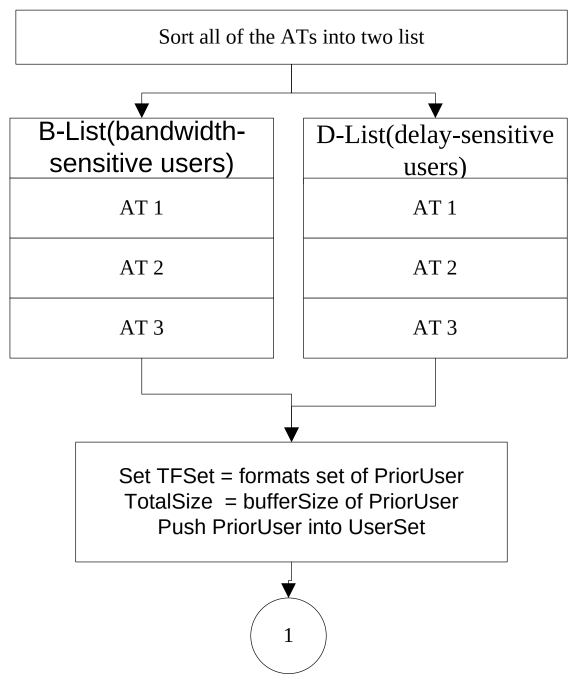



Figure 5 layer 1 scheduling algorithm



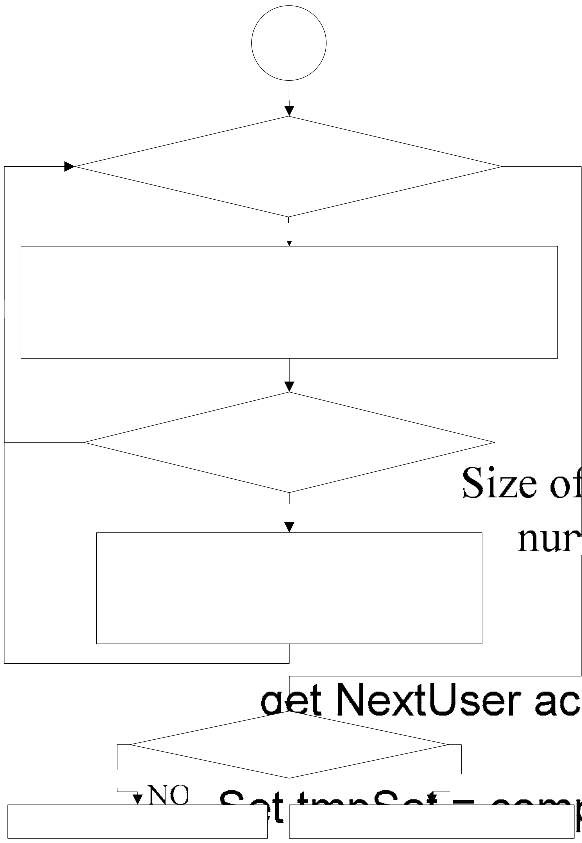


Figure 6 layer 2 scheduling algorithm

1

Size of UserSet < max allowed number of users in MUP

YES

get NextUser according second layer scheduling algorithm

Set tmpSet = compatible formats set for both DRC of NextUser and TFSet

NO

TotalSize + bufferSize of NextUser
<
max packet size in TFSet

YES

Push NextUser into UserSet
Set TFSet = tmpSet
TotalSize = TotalSize + buffer size of NextUser

NO

Size of UserSize == 1

Yes

NO

Transmit single user packet

Transmit multiple user packet