Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>	
Title	**Proposal for Downlink HARQ Scheme**	
Date Submitted	**2008-05-05**	
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Re:	IEEE 802.16m-08/016r1 –Call for Contributions on Project 802.16m System Description Document (SDD); Hybrid ARQ	
Abstract	This contribution covers the considerations about the downlink HARQ schemes for IEEE 802.16m	
Purpose	To be discussed and adopted by TGm for use in the IEEE 802.16m SDD	
Notice		
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Patent Policy		

Proposal for Downlink HARQ Scheme

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1 Introduction

HARQ(Hybrid Automatic Retransmission Request) is a combination of ARQ(Automatic Retransmission Request) and FEC(Forward Error Correction) to further exploit gains from time diversity and better the performance of error correction scheme.

According to the timing of retransmission, HARQ can be classified into ***Synchronous*** and ***Asynchronous*** **HARQ.** Synchronous HARQ defines that retransmission for a certain HARQ process is restricted to occur at known TTI in the frame. There is no need for explicit signaling for the retransmissions. While, asynchronous HARQ defines that retransmission take place at any time in the following frames. Therefore, explicit signaling such as HARQ process number, Redundancy Version and new data indicator is required in asynchronous HARQ processes.

According to retransmission formats (e.g. modulation, code rate, resource block allocation etc.), HARQ can be categorized into ***Adaptive*** and ***Non-adaptive*** **HARQ.** Adaptive means that some or all of transmission attributes may be changed during retransmission comparing to the initial transmission. While, as to non-adaptive HARQ, the format for retransmission is not changed or is known to both MS and BS with a result that the associated control signaling is not required.

From above, we can conclude that synchronous non-adaptive HARQ characterizes as less overhead and simple schedule complexity. Asynchronous adaptive HARQ has more flexibility in transmission and retransmission. Since Bs can acquire more accurate downlink channel estimation, schedule gain can be exploited when applying asynchronous adaptive HARQ in downlink. Also, it is suitable to applying a more flexible scheme in downlink to meet requirements of difference services. However, as described above, asynchronous HARQ causes much more overhead since every retransmission needs almost the same resource allocation signaling as the initial transmission, which decreases the efficiency of transmission dramatically if more HARQ processes are proceeding concurrently.

To acquire trade-off benefit between asynchronous adaptive HARQ and synchronous non-adaptive HARQ, a hybrid HARQ scheme in downlink for TDD system is proposed in this contribution.

2 Design Considerations

2.1 Overhead of HARQ in TDD

In TDD system, the uplink and downlink use the same frequency resource with TDM mode. One radio frame is split into more subframes (8 subframes are assumed). The duration of one subframe is defined as 1 TTI (Transmit Time Interval).

As described above, asynchronous HARQ has its advantages in TDD system such as more flexibility and scheduling gain. However it causes much more overhead than synchronous HARQ.

Take 10MHz bandwidth as example and assume signaling overhead of resource allocation is 12bits, the overhead needed for asynchronous HARQ and synchronous HARQ is compared in Table 1.

Component fields related to HARQ	Asynchronous				Synchronous			
	Adaptive		**Non-adaptive**		**Adaptive**		Non-adaptive	
	Int. Tx	Re Tx	Int. Tx	Re Tx	Int. Tx	Re. Tx	Int Tx	Re Tx
Resource allocation	**12**	**12**	**12**	**0**	**12**	**12**	**12**	0
Modulation and coding scheme	**5**	**5**	**5**	**0**	**5**	**5**	**5**	0
HARQ process number	**3**	**3**	**3**	**3**	**0**	**0**	**0**	0
Redundancy version	**2**	**2**	**0**	**0**	**2**	**2**	**0**	0
New Data indication	**1**	**1**	**0**	**0**	**1**	**1**	**0**	0
CID	**16**	**16**	**16**	**16**	**16**	**16**	**16**	0
Total (bits)	39	39	36	19	36	36	33	0

Table. 1

From Table.1, we can conclude that asynchronous HARQ needs much more overhead than synchronous non-adaptive HARQ. Assuming the number of HARQ processes in one radio frame is M, the total transmission number is N, the overhead of asynchronous adaptive HARQ is M*N*39, the overhead of asynchronous non-adaptive HARQ is M*(39+(N-1)*19)=M*20+M*N*19, the overhead of synchronous non-adaptive HARQ is 33*M. The contrasts of overhead based on the assumption are listed in Table 2.

Overhead(bits)	Asynchronous adaptive HARQ	Asynchronous non-adaptive HARQ	Synchronous adaptive HARQ	Synchronous non-adaptive HARQ
M, N	M*N*39	M*17+M*N*19	M*N*36	33*M
M=5, N=4	780	465	720	165
M=7,N=4	1092	651	1008	231

Table. 2

From Table.2, it is clear that synchronous HARQ has its overwhelming advantage of less overhead. When there are 7 HARQ processes and retransmission number is 4, the overhead of synchronous non-adaptive HARQ is almost 1/5 of asynchronous adaptive HARQ. This will bring gain especially when there are a lot of small amount data transmissions in downlink which overhead takes a relative large part of the total transmission bits.

2.2 Delay of transmission in TDD

In TDD system, additional delay for retransmission has to be considered, which occurs when the radio channel is not immediately available for the necessary UL or DL transmissions. The process delay and frame alignment is supposed to be 2 TTI. So it is not possible for all subframes applying synchronous HARQ in downlink can achieve RTT of 8 TTI at all possible DL/UL ratios. And there will be conflicts of downlink transmission and uplink transmission, which results in different RTTs in the same HARQ process. And further, this may cause more scheduling complexity. For detail see Appendix A.

3 Proposed Downlink HARQ Scheme

The proposed downlink HARQ scheme can be described as follows:

(1) Asynchronous HARQ is the default configuration for downlink;

(2) Synchronous non-adaptive HARQ is applied to some subframes within the Maximum Allowable Synchronous HARQ Region(**MASHR**). These subframes apply synchronous non-adaptive HARQ with RTT of 8 TTI, and are called synchronous HARQ subframes. And the other subframes in the downlink apply asynchronous HARQ with adaptive mode or non-adaptive mode, which are called asynchronous subframes.

(3) The assignments of synchronous subframes are broadcast to all the MSs through bitmap information. And all the MSs can share the same synchronous subframes. The configuration HARQ mode can be fixed or semi-static.

(4) Data transmitted in the synchronous HARQ subframes apply synchronous HARQ, while data transmitted in asynchronous HARQ subframes apply asynchronous HARQ, which is feasible to deal with urgent transmissions and achieve flexibility and scheduling gain.

MASHR is the region which allows fast synchronous HARQ in one frame. The subframes in MASHR can achieve a RTT of one radio frame, that is 8 TTI. The region varies as a function of the TDD frame structure patterns and as a function of the DL/UL ratio.

MASHR can be illustrated in Fig.1, where DL/UL ratio is 6:2. MASHR includes 4 subframes, SF1,SF2,SF3,SF4, which correspond to four synchronous non-adaptive HARQ processes illustrated in (b),(c),(d) and (e). The RTT of these HARQ processes is 8 TTI.

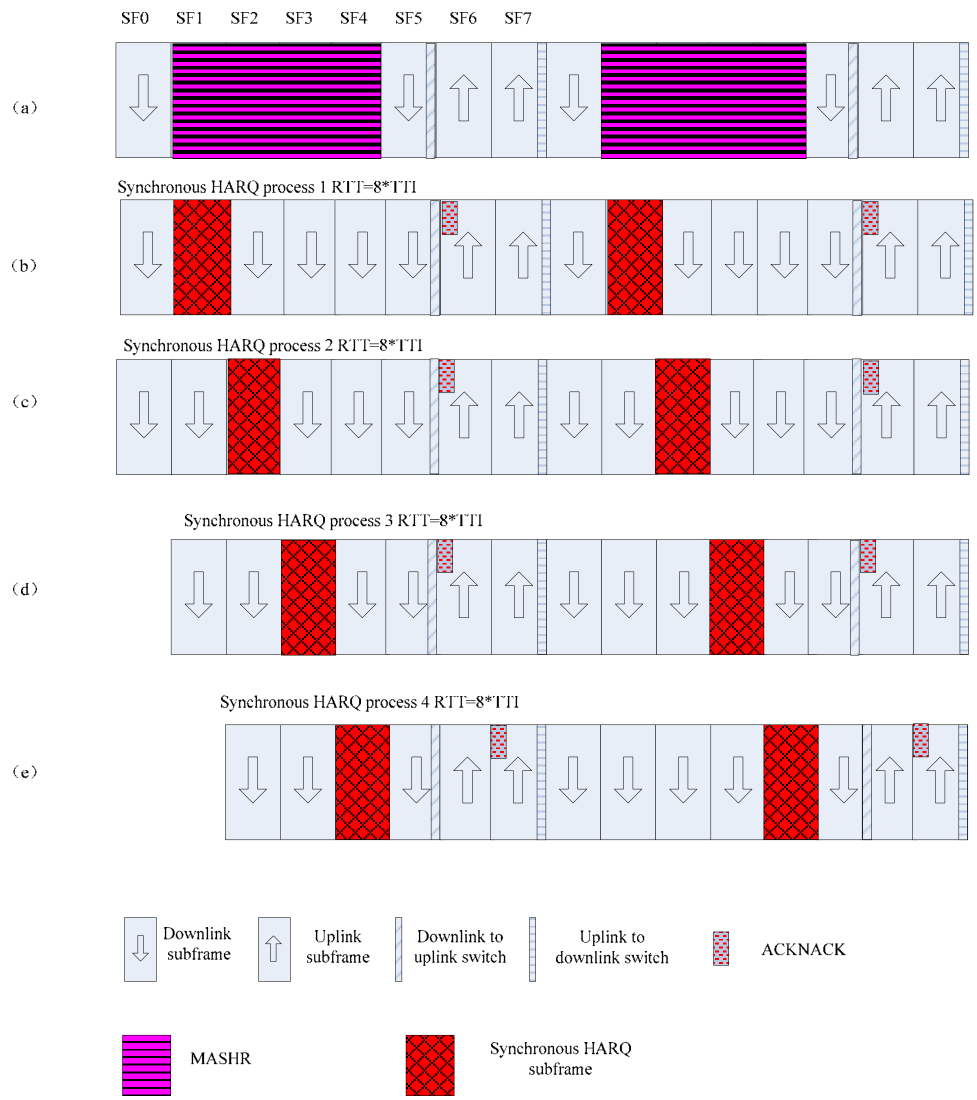

Fig.1

As for SF0, it is possible to be fed back with ACK/NACK in uplink subframe SF6. But it is not possible for it to be retransmitted in the first downlink subframe of the next radio frame, for there is only 1 TTI left between feedback uplink subframe and the first downlink subframe.

For subframe SF5, there is not sufficient time interval for it to get ACK/NACK feedback in the subframe SF7 for the same reason. It can only be fed back by the uplink subframes in the next radio frame.

So, for SF0 and SF5, it is not possible to achieve retransmission with RTT of 8 TTI.

The following are some examples of the proposed downlink HARQ scheme.

(1) DL/UL=6:2

In Fig. 2， the MASHR includes four subframes, SF1, SF2, SF3, SF4, SF5, in which three subframes are chosen to be synchronous subframes, which are SF2,SF3,SF4. And SF0, SF1 and SF5 are asynchronous subframes. Synchronous HARQ processes are illustrated in (c),(d),(e) with RTT of 8 TTI. If one synchronous subframe only contains one HARQ process, the retransmission number is assumed to be 4, the overhead spared by applying synchronous non-adaptive HARQ is 3*4*39=108bits. Obviously, there could be more than one HARQ processes within one subframe with more overhead saved.

Fig.2

(2) DL/UL=5:3

In Fig. 3， the MASHR includes five subframes, SF0, SF1, SF2, SF3, SF4, SF5. One solution is that two subframes are selected to be synchronous subframes, which are SF2,SF3. And SF0, SF1, and SF4 are asynchronous subframes. Synchronous HARQ processes are illustrated in (c),(d) with RTT of 8 TTI.

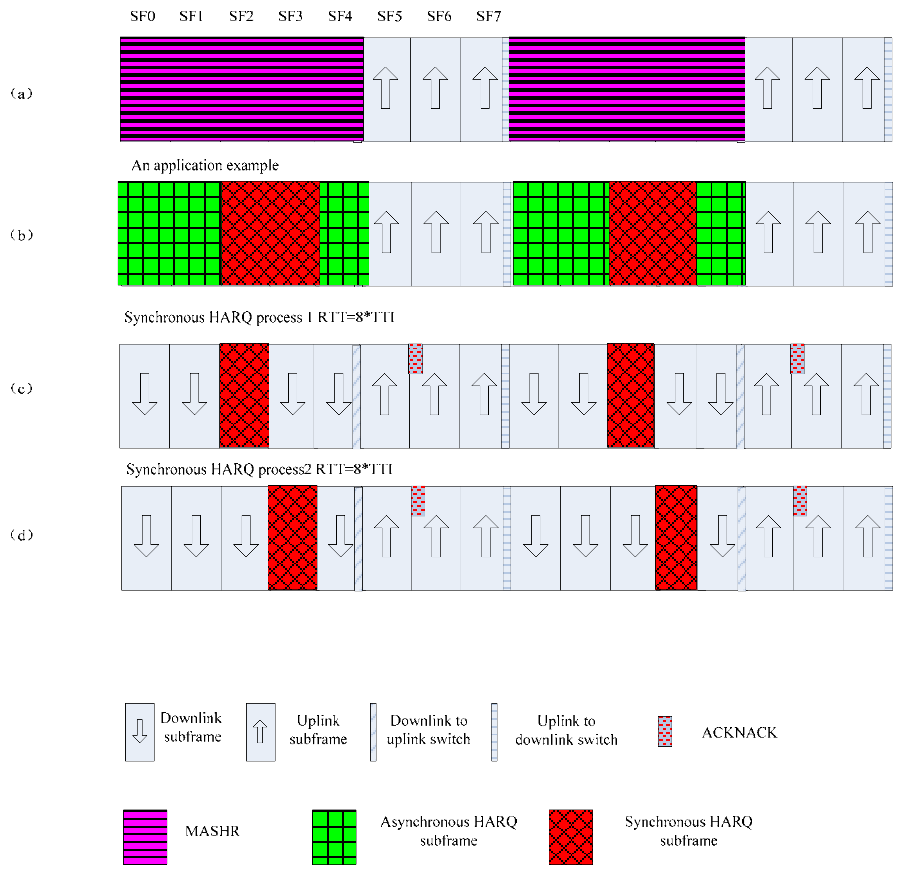

Fig.3

4. Conclusion

In downlink HARQ, synchronous HARQ is applied to some subframes. This could decrease system overhead and increase frequency efficiency. And also, synchronous HARQ is more suitable to some services which demands fast RTT and communicate relatively steadily. And more importantly, this is feasible and beneficial to large number of transmission processes with small payload.

5 Text Proposal for the 802.16m SDD

====================*Start of Proposed Text* ================================

Downlink HARQ Scheme supports both asynchronous HARQ and synchronous HARQ.

Maximum Allowable Synchronous HARQ Region(MASHR) is the maximum subframes that can apply synchronous HARQ with 1 radio frame as RTT. BS notifies MSs the selected subframes which apply synchronous non-adaptive HARQ by broadcasting Synchronous HARQ Subframes Bitmap The selected subframes applying synchronous non-adaptive HARQ are named synchronous subframes; and the subframes applying asynchronous HARQ are called asynchronous subframes. Data transmitted in synchronous HARQ subframes will be retransmitted in the same allocation of the next radio frame with the same modulation and coding rate if MS responses NACK. Data transmitted in asynchronous subframes will use asynchronous HARQ mode. The way to notify MSs the configuration of HARQ mode for each subframes in a radio framed is to send

Synchronous HARQ Subframes Bitmap. This can be further described as follows:

(1)Asynchronous HARQ is the default configuration for downlink subframes;

(2)Synchronous non-adaptive HARQ is applied to some subframes within the Maximum Allowable Synchronous HARQ Region(MASHR). These subframes apply synchronous non-adaptive HARQ with a RTT of 8 TTI, and are called synchronous HARQ subframes. And the other subframes in the downlink apply asynchronous HARQ with adaptive mode or non-adaptive mode, which are called asynchronous subframes.

(3)The assignment of synchronous HARQ subframes is broadcast to all the MSs through Synchronous HARQ Subframes Bitmap. MSs can share the same synchronous subframes.

(4)The configuration HARQ modes can be fixed or semi-static.

The broadcast bitmap information is depicted in the following table.

Table xxx Synchronous HARQ Subframes Bitmap

Name	Length	Value
Synchronous HARQ Subframes Bitmap	8bits	0: subframe applying asynchronous HARQ 1: subframe applying synchronous non-adaptive HARQ

====================*end of Proposed Text* ==================================

6 References

[1] IEEE C802.16m-08/151; Downlink Control Structure related to Hybrid-ARQ; Hyungho Park, Doo-Hyun Sung, Eunjong Lee, HanGyu Cho; LG Electronics,2008.3
[2] IEEE C80216m-08_082r1;Updated Proposal for IEEE 802.16m Frame Structure, Sassan Ahmadi, Hujun Yin; Intel Corporation;2008.3
[3] 3GPP, R1-061671 Comparison of Signaling Overhead between Asynchronous and Synchronous Hybrid ARQ for E-UTRA Downlink;2006.6

Appendix A

Different RTT for the same HARQ process caused by the DL/UL conflict is illustrated in Fig4.

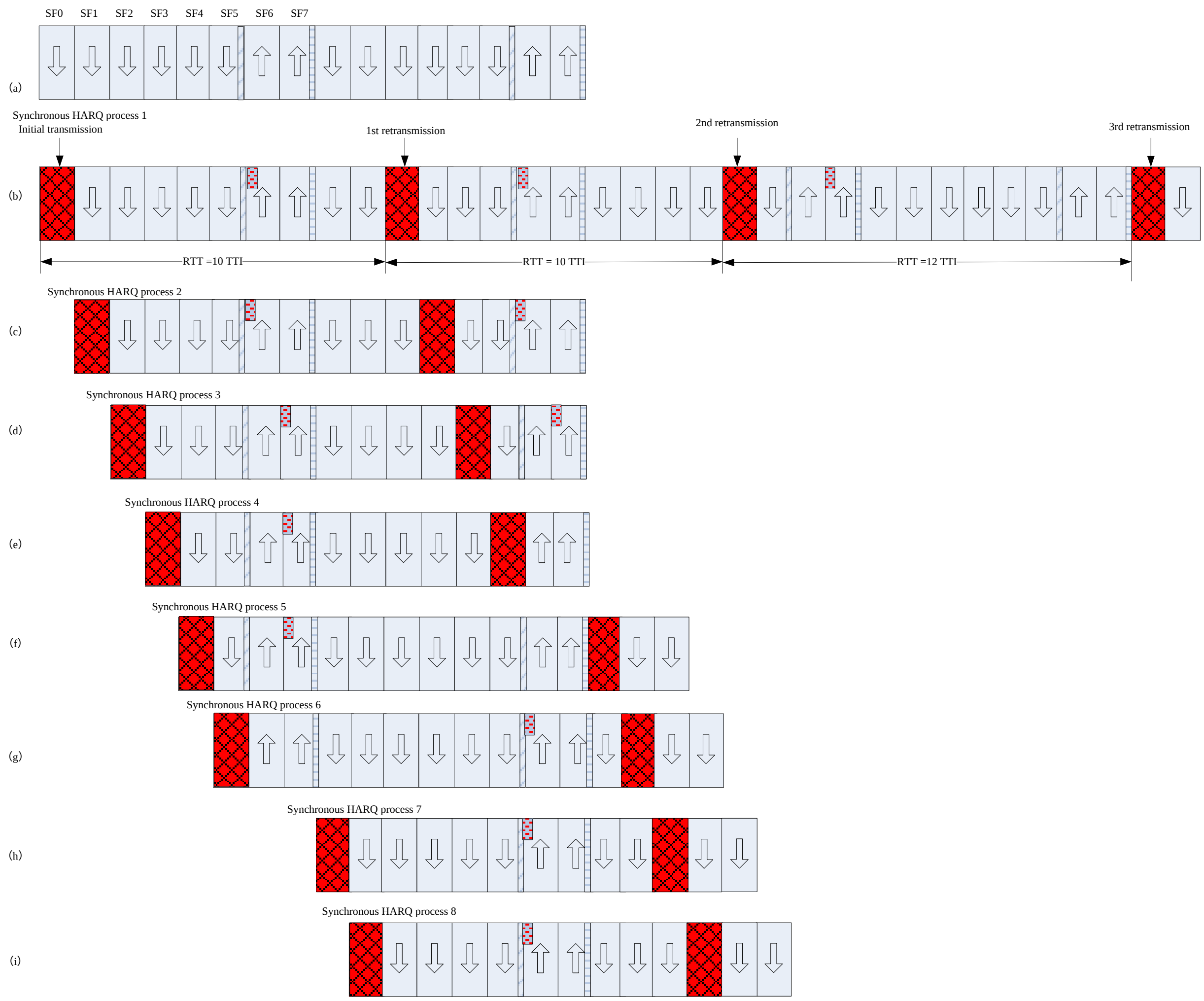

Fig.4

Appendix B

MASHR for different DL/UL ratio:

(1) DL/UL=2:6

In Fig.5, the two subframes in downlink are both configured to be synchronous HARQ subframes.

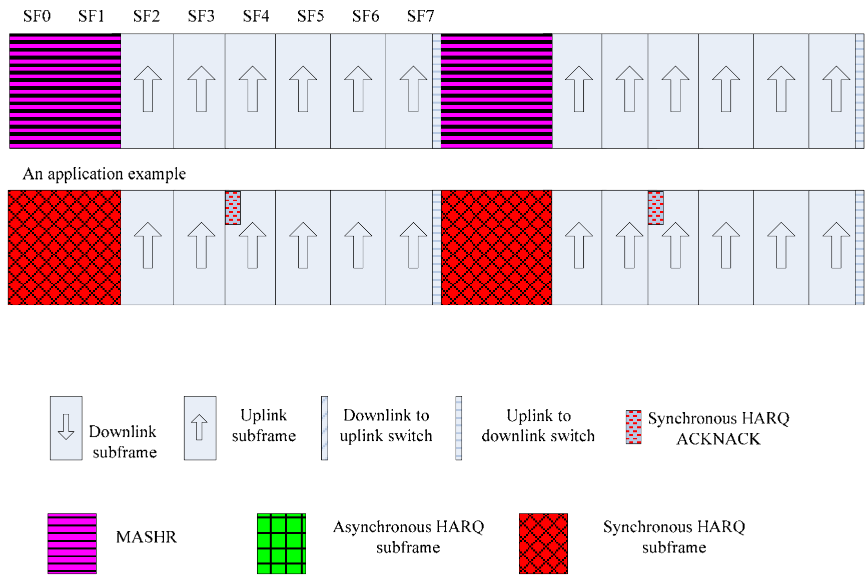

Fig.5

(2) DL/UL=3:5

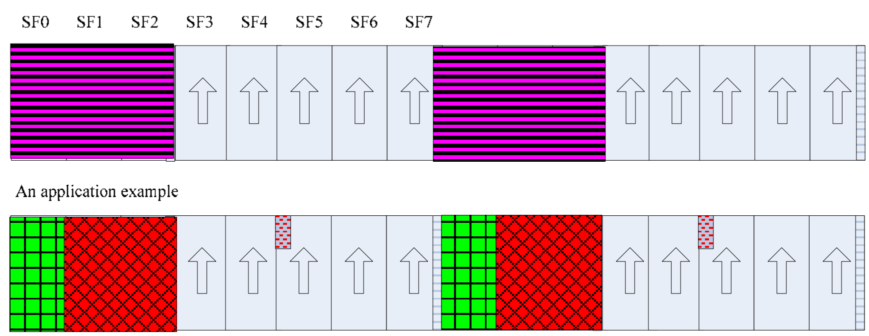

Fig.6

(3) DL/UL=4:4

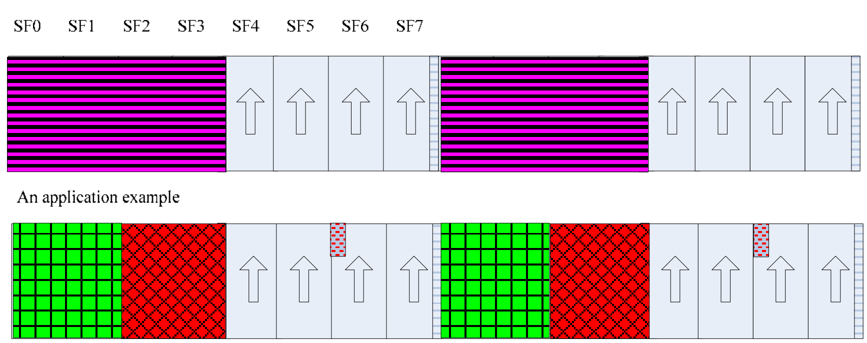

Fig.7

(4) DL/UL=5:3

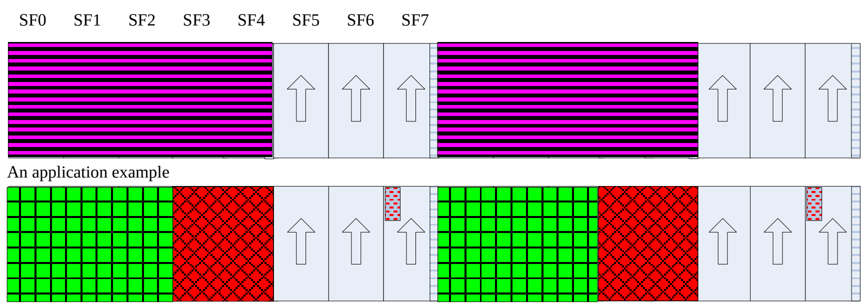

Fig.8

(5) DL/UL=6:2

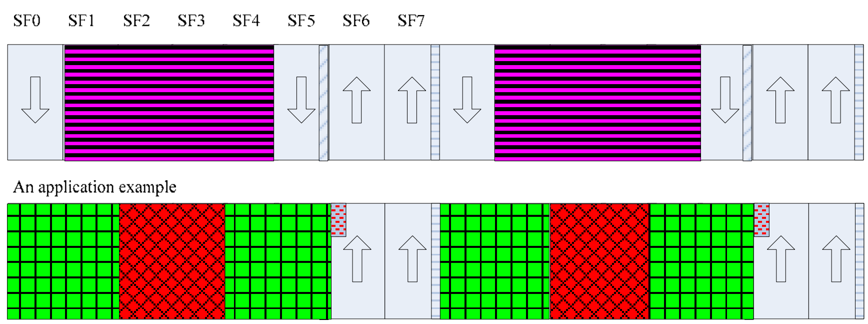

Fig.9