A^2IR - An Asynchronous and Adaptive HARQ Scheme for HSDPA

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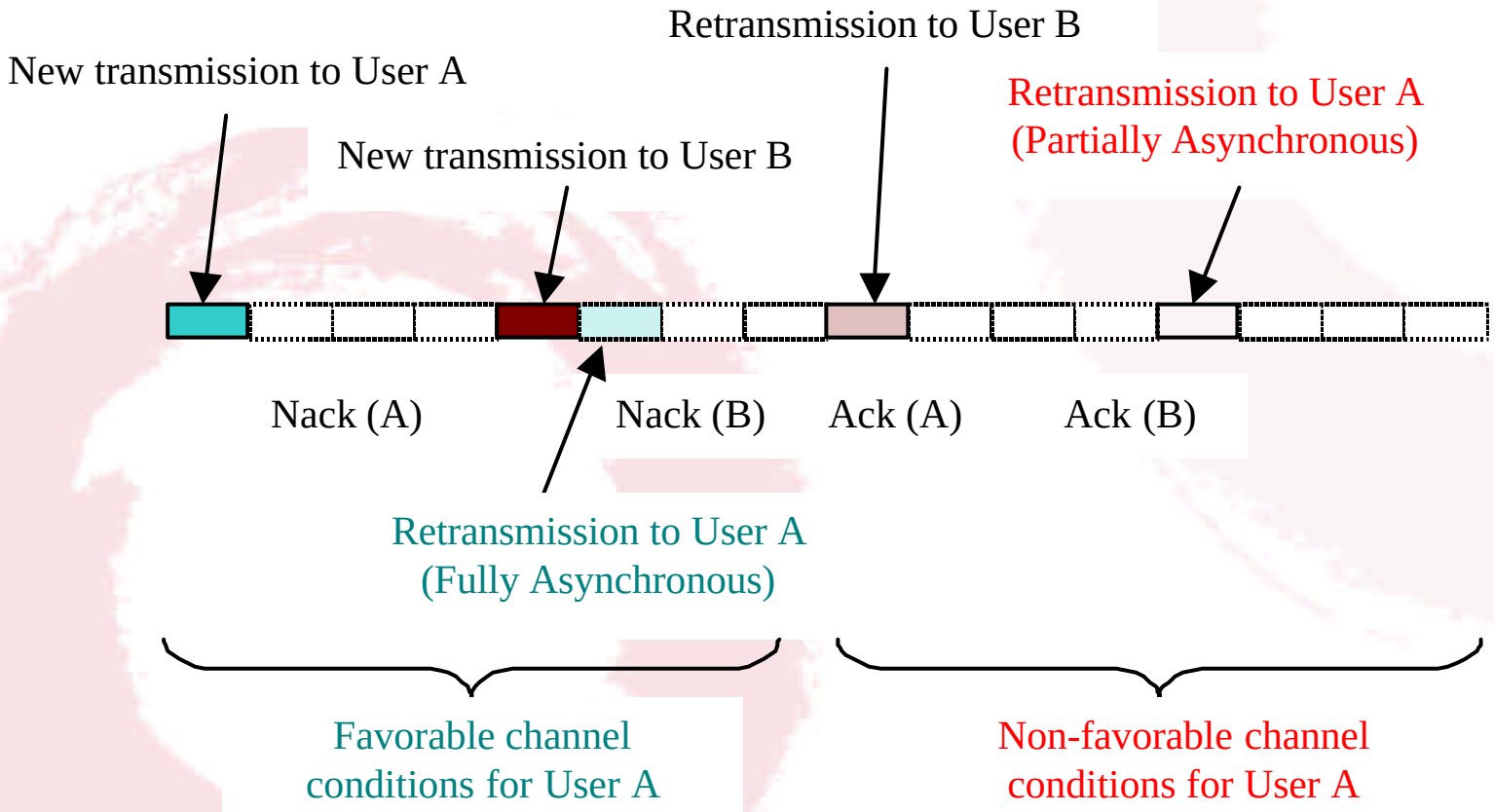
Asynchronous and Adaptive IR

- An Asynchronous and Adaptive IR (A^2IR) scheme that allows to fully exploit the multi-user diversity gains has been proposed for HSDPA [R1-00-1382].
- This contribution provides more details on A^2IR.

Fully Asynchronous Operation (A^2IR)



- A^2IR Supports fully asynchronous operation by using Code Block Identifiers (log2(N) bits for N parallel channels)
- A^2IR provides lower delays and better throughput by fully exploiting multi-user diversity.

A^2IR versus Synchronous IR - An example

Ec/Nt	Throughput [b/s]		AAIR Gain [%]
	SIR	AAIR	
-14	42678	52919	24.00
-12	61013	82287	34.87
-10	86338	131831	52.69
-8	125951	207491	64.74
-6	171450	305618	78.25
-4	235652	445914	89.23
-2	318462	623044	95.64
0	458056	871827	90.33
2	658045	1180479	79.39
4	1076828	1487446	38.13
6	1607128	1819044	13.19
8	1968539	2094262	6.39
10	2214917	2240818	1.17

1.25 MHz carrier
code block size of 3072 bits
8 users
Max. rate user first
30Hz Doppler

A^2IR provides up to 95% throughput gain over synchronous IR

The performance of partially asynchronous scheme is expected to be between synchronous and fully asynchronous scheme (A^2IR)

The CBI (2 bits) overhead in A^2IR is only 0.3% for a code block of size 2560 bits [assumes 4 times higher E_b/N_o for CBI bits]

Why Adaptive Operation? (1)

- The power available for HS-DSCH is continuously changing (on a slot-by-slot basis) due to e.g., large variations in the power used by power-controlled circuit switched users.
- The C/I seen by a user is also varying quickly due to varying interference from neighboring cells and/or large changes in channel quality due to fading etc.
- With asynchronous IR operation, the time between the transmissions/retransmissions could be longer because a retransmission to a user can be preempted by a transmission/retransmission to another user.
- Therefore, it is highly likely that the channel conditions, available power and Walsh code space are different between transmissions/retransmissions that need to be IR/combined.

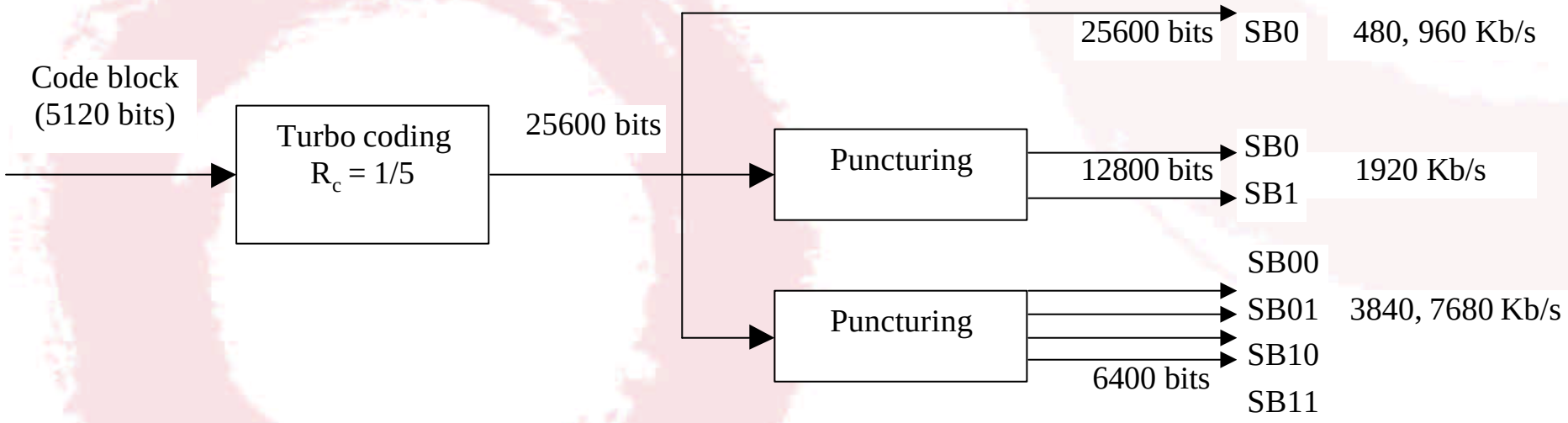
Why Adaptive Operation? (2)

- With fast cell site selection (within a Node B or between Node Bs), the channel conditions, available power and the code space will be different in the new cell.
- With N-channel HARQ, it is highly likely that some of the code blocks will have pending recovery (from the old cell) while FCS is performed.
- Under these conditions, non-adaptive schemes that do not allow change of MCS on retransmissions will have to abort transmission that will result in degraded system performance.
- A true HARQ scheme should be able to do IR/combining across transmissions/retransmissions at different MCS within the same cell and across cell sites.

Key features of A²IR

- The scheme supports fully asynchronous operation in order to exploit the multi-user diversity gains.
- The scheme provides the flexibility to perform IR/Combining across different rates (different modulation and coding schemes including MIMO).
- The scheme also allows the flexibility of selecting different code block sizes (number of Transport blocks per TTI) for the same data rate in order to avoid the frame-fill inefficiency.
- The scheme can be operated in pure rate controlled (link adaptation) mode [8/10 different MCS are provided].
- The scheme operates transparently with Fast Cell Site Selection i.e., any modulation and coding scheme can be used to recover outstanding (ongoing transmission) code blocks in the new cell.

Encoding and sub-block formation (Example)



Mapping of sub-blocks to slots

Data Rate [Kb/s]	sub-block size [bits]	Modulation	Repetition factor	Modulated symbols	Symbols after spreading	Number of slots/sub-block
480	25600	QPSK	2	25600	40960	16
960	25600	QPSK	1	12800	20480	8
1920	12800	QPSK	1	6400	10240	4
3840	6400	QPSK	1	3200	5120	2
7680	6400	16-QAM	1	1600	2560	1

Modulation and coding schemes (non-MIMO)

MCS	Data Rate [Kb/s]	Modulation	Effective coding rate [actual coding + repetition]	Transmission Time Interval (TTI) [number of slots]			
				16 Transport blocks per TTI [code block = 5120 bits]	8 Transport blocks per TTI [code block = 2560 bits]	4 Transport blocks per TTI [code block = 1280 bits]	2 Transport blocks per TTI [code block = 640 bits]
1	60	QPSK	0.0125				16
2	120	QPSK	0.0250			16	8
3	240	QPSK	0.0500		16	8	4
4	480	QPSK	0.1000	16	8	4	2
5	960	QPSK	0.2000	8	4	2	1
6	1920	QPSK	0.4000	4	2	1	
7	3840	QPSK	0.8000	2	1		
8	7680	16-QAM	0.8000	1			

Modulation and coding schemes (MIMO - 2 Receive Antennas)

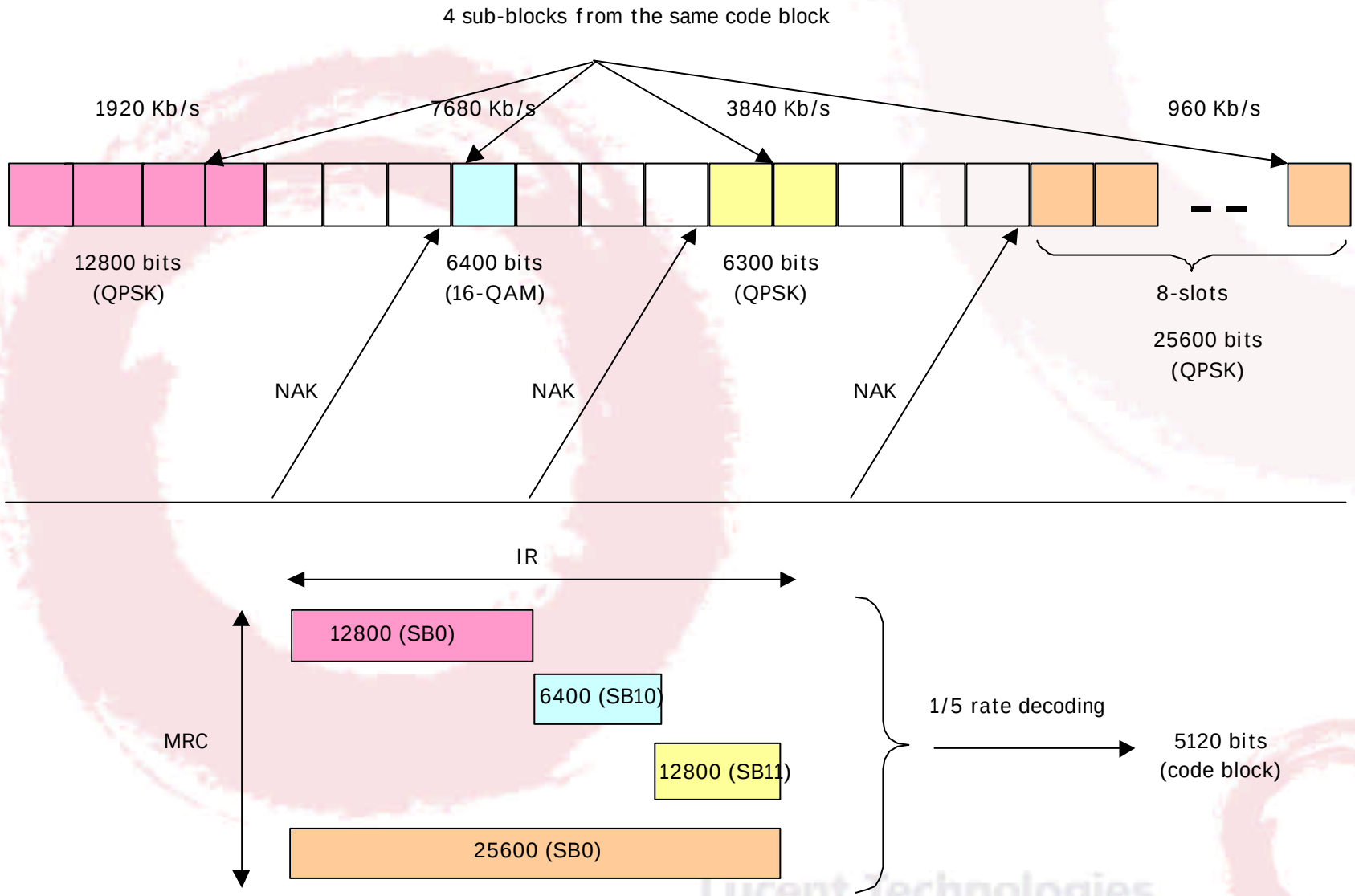
MCS	Data Rate [Kb/s]	# of transmit antennas	Modulation	Effective coding rate [actual coding + repetition]	Transmission Time Interval (TTI) [number of slots]	
					32Transport blocks per TTI [code block = 10240 bits]	16 Transport blocks per TTI [code block = 5120 bits]
4	480	1	QPSK	0.1		16
5	960	1	QPSK	0.2	16	8
6	1920	1	QPSK	0.4	8	4
7	3840	1	QPSK	0.8	4	2
8	7680	2	QPSK	0.8	2	1
9	15360	2	16-QAM	0.8	1	

A²IR also allows HARQ (IR/combining) operation across MIMO and non-MIMO modulation and coding schemes.

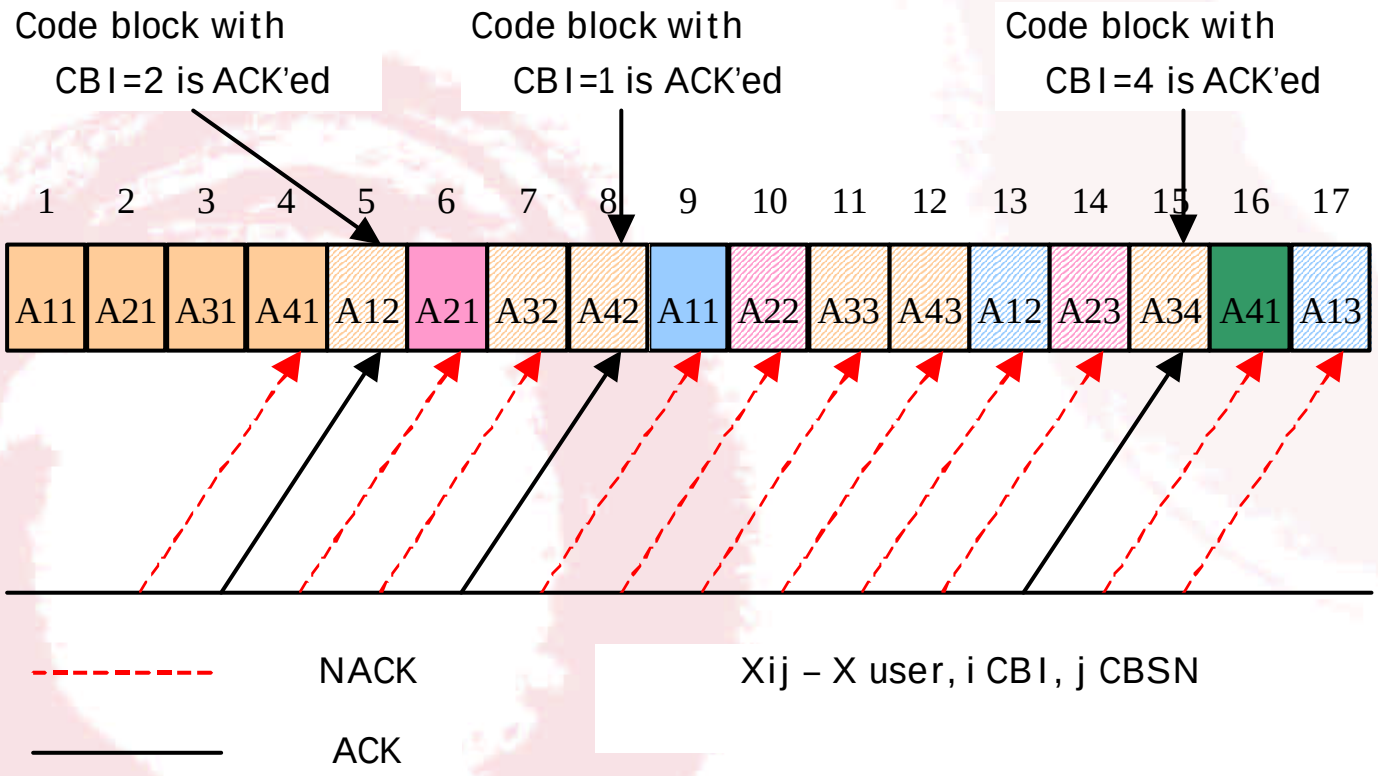
Sub-block rate (SBR)

Supportable rate [Kb/s]	Sub-block rate (SBR) [Kb/s]
15	60
30	120
60	240
120	480
240	960
480, 960	1920
1920	3840
3840	7680
7680	7680

Operation Across Different MCS



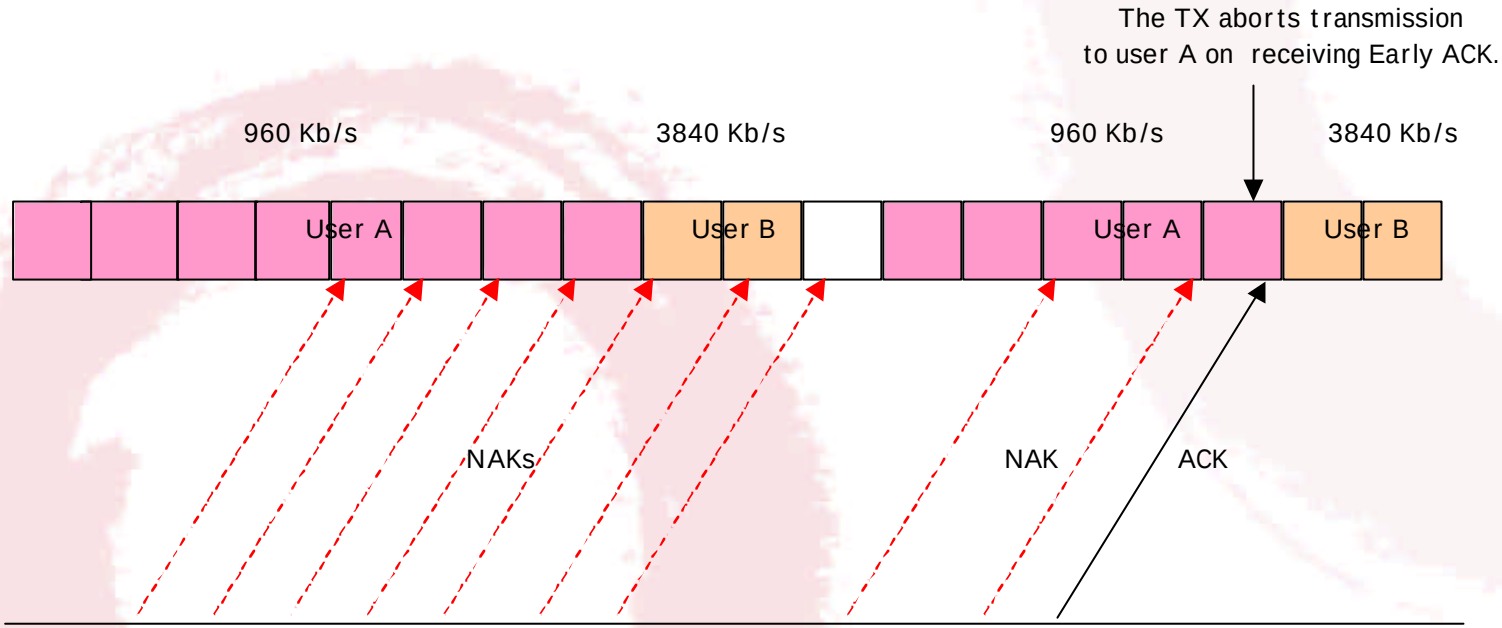
Parallel code block Transmission (Example)



2-bit Code Block Identifier (CBI) is used to distinguish up to 4 parallel transmissions (N-channel) from the same user.

2-bit sub-block sequence number (SBSN) is used to identify the sub-blocks (generalized New/Continue indication).

Early ACK



The Early ACK feature of the A²IR scheme can reduce the transmission times and improve throughput for cases where the sub-block transmission time is greater than the ACK/NACK feedback delay.

Summary of Key features

- The scheme supports fully asynchronous operation in order to exploit the multi-user diversity gains.
- The scheme provides the flexibility to perform IR/Combining across different rates (different modulation and coding schemes including MIMO).
- The scheme also allows the flexibility of selecting different code block sizes (number of Transport blocks per TTI) for the same data rate in order to minimize the frame-fill inefficiency.
- The scheme can be operated in pure rate controlled (link adaptation) mode [8/10 different MCS are provided].
- The scheme operates transparently with Fast Cell Site Selection i.e., any modulation and coding scheme can be used to recover outstanding (ongoing transmission) code blocks in the new cell.