R2-060944 HARQ Considerations

Motorola

Agenda Item 3.4

Variable TTI

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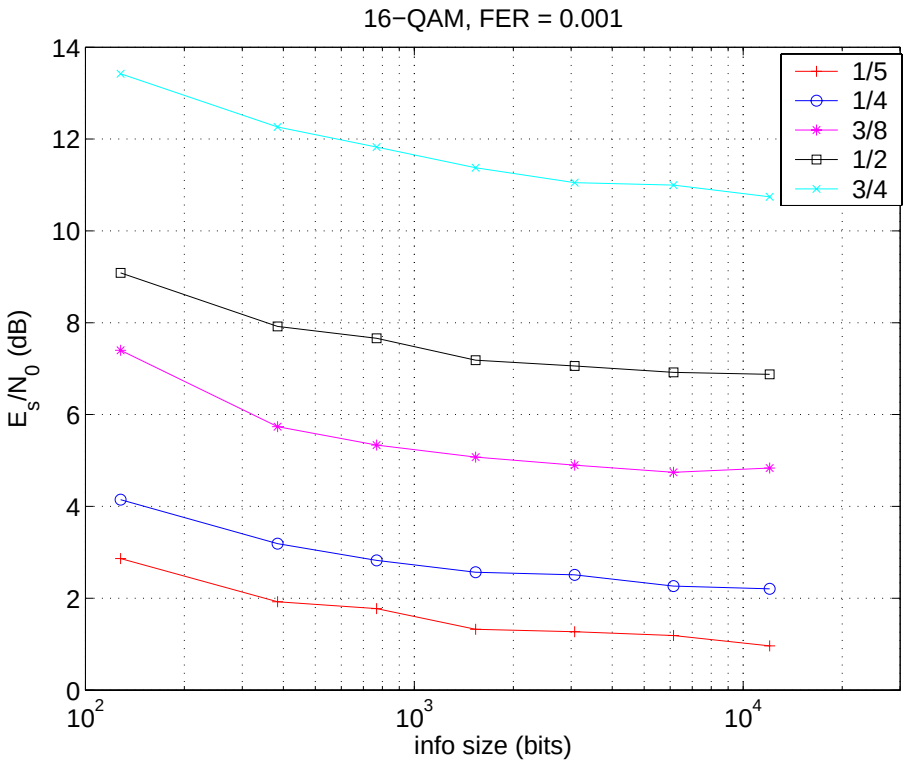
- Support of 0.5 sub-frame length primarily governed by desire to reduce control signaling latency
- Channel coherence typically longer than 0.5 ms
- Significant coding gain accrues from longer code blocks especially with turbo codes. LDPC codes. etc.



Transmission times for 1500 byte packet

- **Number of sub-frames required to transmit MTU sized IP packet (1500 bytes) for 5MHz**
  - **Higher data rates possible with MIMO**
  - **Each sub-frame would require control signaling, feedback signaling and associated protocol overhead without the ability to vary TTI size to the IP packet size**

Modulation	Coding Rate	Information Bits/Frame	# Consecutive Sub-frames
QPSK	1/5	600	20
	1/4	750	16
	1/2	1500	8
	3/4	2250	5.33
16QAM	1/2	3000	4
	3/4	4500	2.67
	5/6	5000	2.4
64QAM	1/2	4500	2.67
	3/4	6750	1.67
	5/6	7500	1.6

Signaling overhead for IP packets

- **Advantageous to reduce overhead of L2 protocol (MAC, RLC) layers due to segmentation of IP packets**
- **Further benefits result due to reduced feedback required with long code blocks**
  - **Each IP packet requires one CRC (and therefore only one ACK/NACK) as opposed to multiple CRC (requiring multiple ACK/NACKs) for every segment transmitted over the radio**
  - **Secondary benefit of improving overall performance due to NACK->ACK error**
    - With segmentation, probability of error (with the receiver consequently flushing SDU) proportional to number of segments

Benefits of variable TTI

- **Sending IP packet as is without segmentation leads to overall reduction in control signaling**
  - **It avoids unnecessary fragmentation of packets in upper L2 protocol layers due to L1 transmission constraints and consequentially also reduces L2 control signaling/feedback.**
- **The coding gain derived from the scheme leads to reduced latency due to optimal resource utilization and assists with further exploitation of the fat-pipe scheduling concept in good channel conditions.**
- **Better resource utilization for the good geometry and high bandwidth users permits better resource allocation for users in low geometry conditions thereby <u>increasing cell-edge performance</u> and <u>overall throughput</u> and hence <u>spectral efficiency</u>.**

HARQ Schemes

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- **Incremental Redundancy**
  - **Chase, Partial Chase included**
- **N-channel SAW**
  - **N = 6 can be supported with TTI=0.5 ms**
    - RTT and processing requirements can be met
- **Process pool configuration**
  - **Configure N processes where N is larger than the number M prescribed by RTT and processing time considerations**
  - **Pool of processes can then be shared among transport channels assigned to UE**
    - Transport channel may be assigned short or long TTI

Synchronous HARQ

- Scheduler assigns HARQ Process tied to a sub-frame
  - Process recurs periodically in the N-cycle sequence
- Time-frequency resource can also be tied to this HARQ Process
  - Limit assignment to initial transmissions only
- Advantages
  - HARQ process need not be signaled (synchronicity fundamentally tied to process occurrence)
  - Possible to avoid signaling of resource assignment assuming reliable detection of first transmission
  - Reduction in error cases due to deterministic nature of scheme
  - Possible to improve control channel reliability through soft-combining assuming no abortion
- Pre-emption less of an issue due to smaller sub-frame size
- Chase combining – resource assignment is identical
  - Needs to be signaled to account for missed assignments
- IR – adaptive IR requires signaling of resource assignment sized for retransmission
  - Also useful for frequency selective scheduling and for efficient distributed allocation

PRIMARY ADVANTAGE OF SYNCHRONOUS HARQ: NO NEED TO SEND HARQ PROCESS IDENTITY (savings of ` 3 - 4 bits)

Asynchronous HARQ

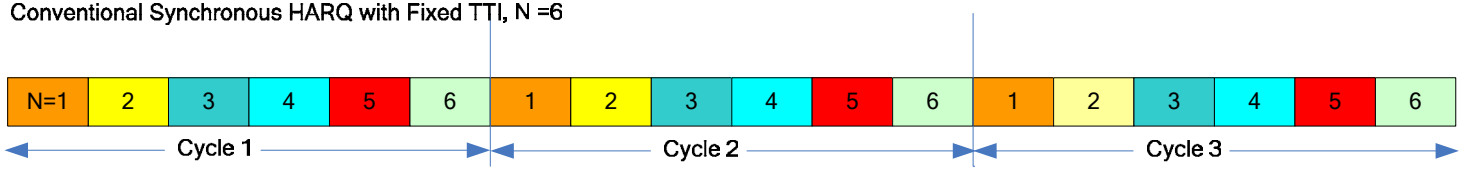
- HARQ process explicitly identified
- Assuming reliable first control signal transmission possible to avoid signaling resource assignment in retransmissions
- Advantageous to signal resource assignment for retransmission based on resource needs for retransmissions and time varying channel conditions

Synchronous HARQ – Variable TTI case

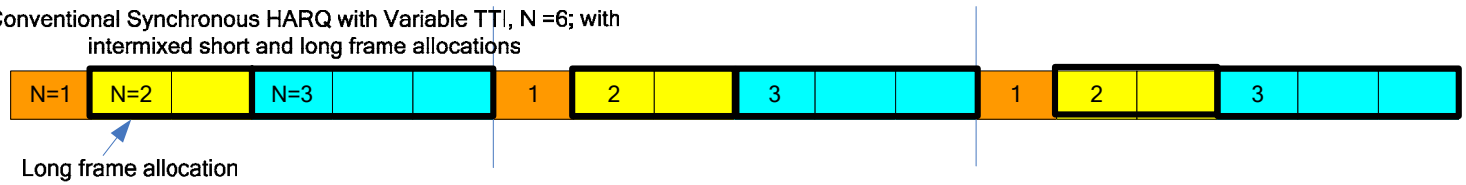
- **Modified synchronous scheme**
  - **Mobile assigned a process and this is tied to the frame currently in use for transport channel**
  - **Process is tied to the first sub-frame when a Long frame (long TTI) first transmission is assigned in order to define the synchronicity relationship**
  - **Retransmissions <u>may</u> use corresponding frame in following cycle;**
    - UE Identity always sent in control signaling;
    - TTI also indicated *along with redundancy version;*
    - *Resource allocation can also be different from that used for initial transmission.*
  - **Can be applied to Variable TTI**
  - **By supporting larger N than required by RTT and processing time requirements, it is possible to pre-empt transmissions**

Synchronous HARQ with Short and Long frame allocations for one UE

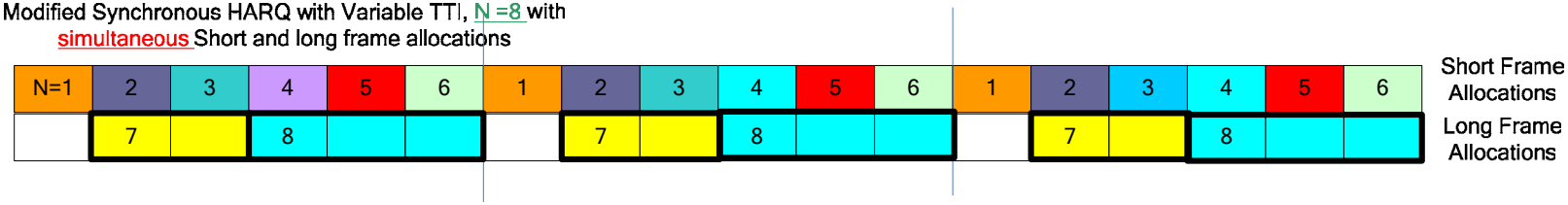
Conventional Synchronous HARQ with Fixed TTI, N =6



Conventional Synchronous HARQ with Variable TTI, N =6; with intermixed short and long frame allocations



Modified Synchronous HARQ with Variable TTI, N =8 with simultaneous Short and long frame allocations

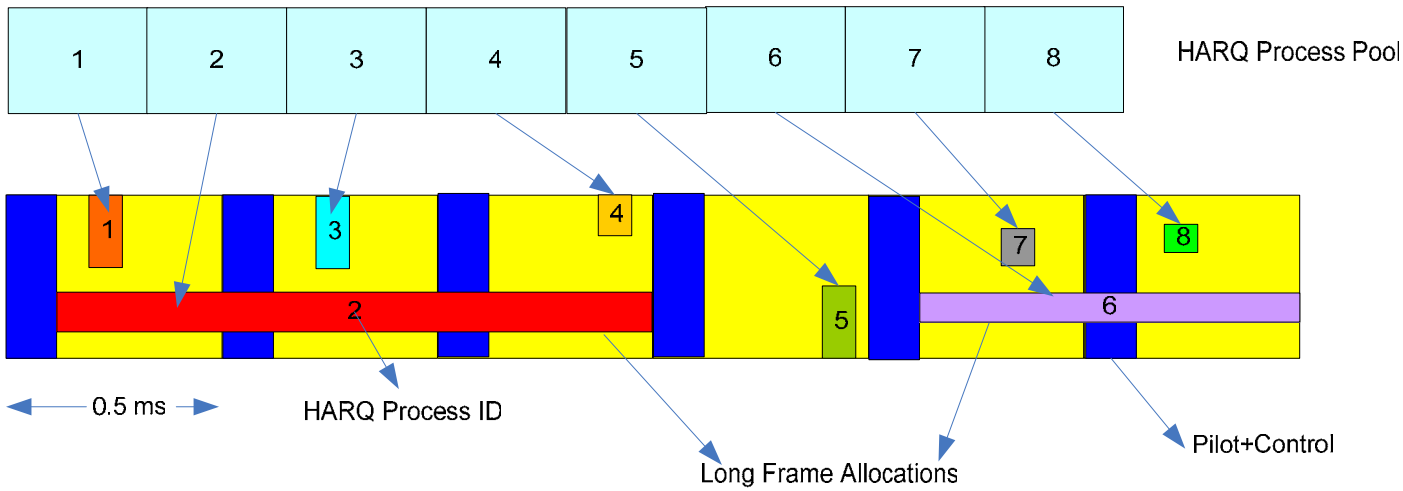


Here each one of such blocks (length conforms to short/long frame allocation) refers to a particular Resource Block Assignment in one sub-frame that is mapped to a HARQ process to one UE. Block indicates time instance when process is active; buffer size can be distinct for each process/block. It is assumed that every process requires three retransmissions at least (illustrative purposes only).

Asynchronous HARQ scheme – Simul. Short and Long Frame Alloc

- **Asynchronous**
  - **Similar to current HSDPA scheme**
  - **Mobile is assigned a Short or Long frame; Process identity and UE identity are explicitly sent through the shared control channel using shared control channel**
    - No implicit tying of sub-frame to process identity
  - **Resource Assignments may span multiple subframes (variable TTI)**
    - Resource Assignment is effectively a short or long frame
  - **A pool of N (N > 6) processes is used**
    - Permits assignment of simultaneous processes to multiple Resource Assignments to one UE where the resource allocations reside in same subframe
      - Resource allocations may be mapped to either short or long frames
  - **HARQ process memory requirement is dependent on whether process is mapped to long or short frame**
    - total maximum process memory capability defined for a UE class

Asynchronous HARQ scheme – Simul. Short+Long (2)



- **Figure illustrates a single cycle (6 subframes long) of a N=8, M=6 Asynchronous HARQ scheme that permits multiplexing of short and long frame allocations to one UE.**
  - **Can be seen as applicable for case with multiple transport channel assignments within a sub-frame**
  - **the Mth (here M = 6) sub-frame after the end of the transmission can be used for retransmissions**
    - M defeins minimum feedback cycle length

HARQ Considerations

- Primary advantage for synchronous HARQ stems from saving control bits required to identify HARQ process (~ 3 – 4 bits).
- Support of adaptive IR schemes requires retransmission of resource assignment.
- Advanced schemes likely necessary in order to support high spectral efficiency and peak data rates targets.
- Given the rather small savings from synchronous HARQ, and potentially significant flexibility and performance benefits from asynchronous HARQ, it is beneficial to consider asynchronous HARQ for both UL and DL.