Agenda item: **AdHoc #24 HSDPA**

Source: **Motorola**

Title: **Recommendation on TTI size for HSDPA**

Document for: **Discussion/Information**

Summary:

This contribution shows system throughput performance for different TTI sizes. The TTI sizes examined were 0.667ms, 2.00ms, and 3.33ms or 1, 3, and 5 slots. It was found that a TTI of 2.00ms provided the best throughput when accounting for control channel overhead for a 3kph Rayleigh channel.

Simulation Results:

The throughput for best effort service is summarized in the following section. **Table 1** summarizes performance difference for a data only HSDPA system with a Maximum C/I scheduler and a modified ETSI source model [2] for different TTI sizes. The different throughput metrics presented are defined in **Annex A**. The MCS used were QPSK R=1/2, 16QAM R=1/2, 16QAM R=3/4, and 64QAM R=3/4.

Table 1. Throughput (%) change as TTI sizes go from 5 to 3 and 3 to 1 slots given a 3kph Rayleigh Channel with FRP=0.98.

Max C/I, Mod. ETSI 30% Overhead AMC, HARQ, no FCS

Throughput Metric	TTI sizes compared	12 ue per sector	37 ue per sector	56 ue per sector	100 ue per sector
Sector (Service) Throughput	5 vs 3	2	-1	1	2
	3 vs 1	2	0	0	0
OTA (Frame) Throughput	5 vs 3	0	2	3	1
	3 vs 1	5	8	6	5

From **Table 1** above, the OTA throughput shows about a 6% improvement going from a 3 slot to 1 slot TTI for a 3kph Rayleigh channel with 0.98 fraction of recovered power (FRP). The OTA throughput increase is mainly attributed to better tracking of the varying interference level and to a lesser extent improved multi-user scheduling benefit. Sector throughput shows little improvement (3 vs 1 case). Some of the potential throughput improvement is mitigated by the reduction in turbo coding interleaver benefit for the smaller TTI sizes. The benefit of a smaller TTI at 3kph is mainly due to better tracking of the interference variation. At the peak load interference variation is much smaller hence there is little benefit to having a smaller TTI and the turbo code interleaver loss dominates. While it is possible that there would be some additional benefit to using a single slot TTI at speeds above 3kph this must be weighed against degradation caused by C/I measurement inaccuracy with the smaller TTI interval and also the increased power overhead due to the associated control channels.

Associated Control Channel Overhead:

Table 2 and 3 show possible control channel bit allocations in order to estimate the Ec/Ior overhead that a scheduled user would require for the 3 slot and 1-slot TTI cases. In this example, it is assumed that the HS-DSCH Indicator and the SHCCH are sent at the same time as the HS-DSCH. Based on the subsequent analysis there is about a 4 percentage point increase (see Table 4) in the fraction of total power (Ec/Ior) required for the average control channel power allocation in the 1 slot TTI case compared to the 3 slot case for a typical geometry of 3dB.

Table 2. HS-DSCH Associated Control Channel Payload Map for 3 slot TTI

HS-DSCH Indicator **OVSF Code SF=512**	**#bits** **30**		**SHCCH Bit Map** **OVSF Code SF=512**	**#bits** **30**
TPC	*06*		CRC	08
Dedicated Pilot	*06*		MCS	03
SHCCH identification	03		HS-DSCH power level	06
HSUPA reserved bits	02		FHARQ packet number (abort bit)	01
Code Channels	05			
Total Bits to be coded	10		Total Bits to be coded	18

Table 3. HS-DSCH Control Channel Payload Map for 1 slot TTI

HS-DSCH Indicator **OVSF Code SF=256**	**#bits** **20**		**SHCCH Bit Map** **OVSF Code SF=128**	**#bits** **40**
TPC	*02*		CRC	08
Dedicated Pilot	*02*		MCS	03
SHCCH identification	03		HS-DSCH power level	06
HSUPA reserved bits	02		FHARQ packet number (abort bit)	01
Code Channels	05			
Total Bits to be coded	10		Total Bits to be coded	18

The average power required for the HS-DSCH Indicator and the SHCCH is derived for a single Rayleigh path channel with FRP=0.98 given the bits are allocated as given by Tables 1 and 2 above. Transmit diversity and fast forward power control are assumed. The fraction of power allocated to a given channel is given by

$$E_c/I_{or} = \frac{E_b/N_t}{FRP\cdot(W/R)}\left((I_{oc}+N_o)/I_{or}+(1-FRP)\right) \qquad (1)$$

where W/R = SF * Encoding Rate

Therefore, the Ec/Ior can be calculated for the HS-DSCH Indicator and the SHCCH assuming a target average Eb/Nt of 13 dB is needed to achieve a FER less than 1% and assuming an average geometry (G) of 0 dB as given by

$$G = \hat{I}_{or}/(I_{oc}+N_o) \qquad (2)$$

then

E_c/I_{or_3slots} = (20/(0.98*512*(18/10)))*((1.0+0.02)) + (20/(0.98*512*(30/18)))*((1.0+0.02)) = 0.047

E_c/I_{or_1slots} = (20/(0.98*256*(16/10)))*((1.0+0.02)) + (20/(0.98*128*(40/18)))*((1.0+0.02)) = 0.124

$E_c/I_{or\_1}/E_c/I_{or\_3}$ = (1/(256*(16/10)) + 1/(128*(40/18))) / (1/(512*(18/10)) + 1/(512*(30/18))) = 2.64

Table 4 Geometry vs. Control Channel Ec/Ior for a given TTI size

G	Associated CCH Ec/Ior*		Ec/Ior when DTXed Info Bits**	
	3 slot TTI	1 slot TTI	3 slot TTI	1 slot TTI
(dB)	(%)	(%)	(%)	(%)
-3	9.3	24.5	1.01	1.01
0	4.7	12.4	0.51	0.51
3	2.4	6.3	0.26	0.26
6	1.2	3.3	0.14	0.14

* Total Ec/Ior of both HS-DSCH Indicator and SHCCH when UE scheduled

** Target Eb/Nt for TPC and Pilot only is 8dB, Only TPC & Pilot transmitted in DTX mode

Note that it is assumed that the information bit portion of the HS-DSCH indicator channel would be DTXed when the user was not scheduled. The actual Ec/Ior given in **Table 4** for the active case (non-DTX) represent a worst case average since to some extent the control channels get the same multi-user scheduling benefit as the HSDPA HS-DSCH (even if the HS-DSCH Indicator channel is advanced by one slot (see **Figure 2 and 3**).

Recommendation:

It is recommended that a TTI size of 2.00ms (3 slots) be adopted for HSDPA HS-DSCH.

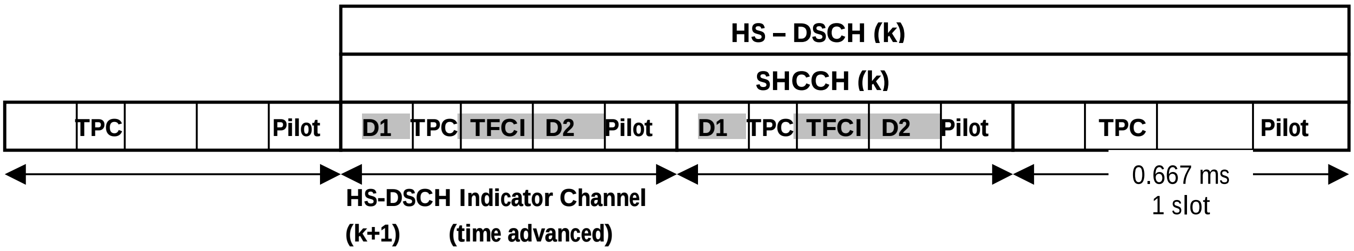


Figure 2. Timing of HS-DSCH, SHCCH, and time advanced HS-DSCH Indicator Channel. HS-DSCH Indicator (HI) Channel contains code space information for next HS-DSCH and SHCCH. In this case the HI Channel could be 2 (shown) or 3 slots like the HS-DSCH and SHCCH. A 3 slot HI channel requires less power.

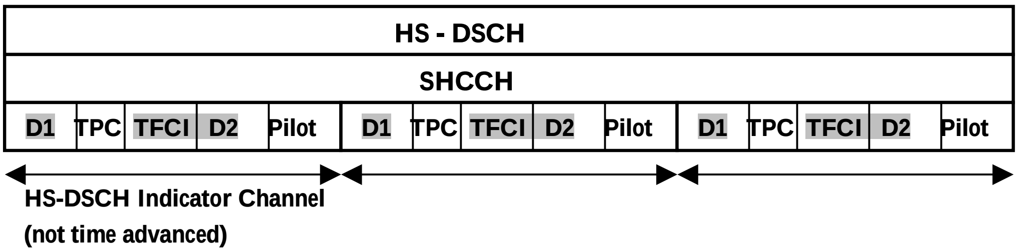


Figure 3. Timing of HS-DSCH, SHCCH, and HS-DSCH Indicator Channel when HS-DSCH Indicator Channel is not time advanced. TTI is 3 slots for all 3 channels and they are coincident such that all three would therefore be buffered and decoded at the same time. Information bits are in grey for current HI channel slots.

References:

[1] Motorola. HSDPA system performance based on simulation II. TSG-R1 document, TSGR#17(00)1397, 20-24th November 2000, Stockholm Sweden, 8pp.

[2] Nokia, Ericsson, Motorola. Common HSDPA system simulation assumptions. TSG-R1 document, TSGR#15(00)1094, 22-25th, August, 2000, Berlin, Germany, 12 pp.

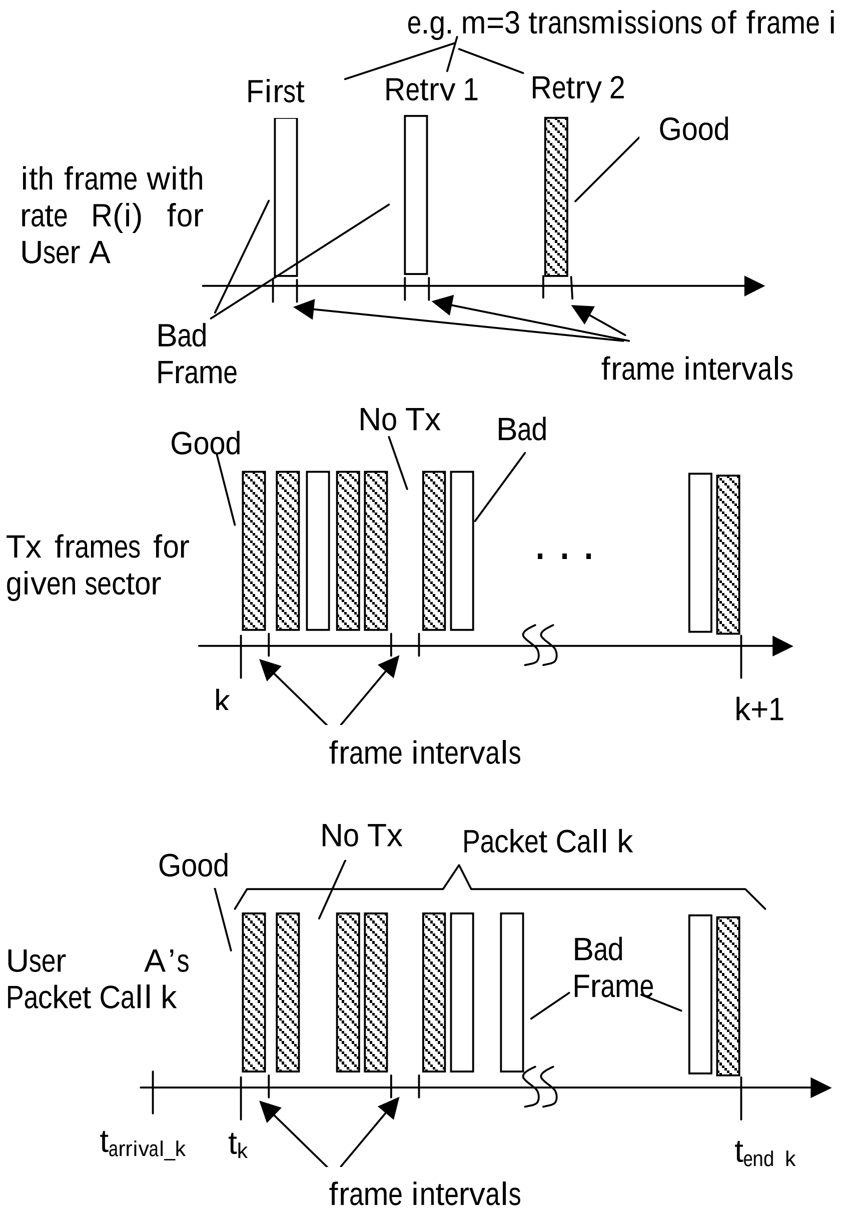
[3] Motorola. Evaluation Methods for High Speed Downlink Packet Access (HSDPA). TSG-R1 document, TSGR#14(00)0909, 4-7th, July, 2000, Oulu, Finland, 15 pp.

[4] Motorola. HSDPA system performance based on simulation. TSG-R1 document, TSGR#16(00)1240, 10-13th October 2000, Pusan Korea, 12pp.

Annex

Throughput Statistic Descriptions

OTA – over the air per frame throughput, Frame Rate/#transmissions. (Unaffected by time between retries.)
Service – total good (successful) frame bits transmitted per second for a given sector. As observed from BTS including all users and idle time. (Affected by time between retries).
Packet Call - total bits per packet call divided by total time to transmit packet call.
Utilization – percentage of time that frame intervals are active for a given sector.
(active = transmission occurs on downlink shared channel).



$$OTA(i) = \frac{R(i)}{m(i)}$$

$$OTA = \sum_{i=1}^{N_{good\_frames}} R(i) \Big/ \sum_{i=1}^{N_{good\_frames}} m(i)$$

(Averaged over all users)

$Service(k)$ =# good bits in kth second interval (for any user)

$$Service = \frac{\sum_{k=1}^{N_{seconds}} Service(k)}{N_{seconds}}$$

Aggregate Packet Call Throughput of user i from sector j

$$S_{user}(i, j) = \frac{\sum_{k=1}^{K} \text{bits in pkt call k}}{\sum_{k=1}^{K} (t_{end\_k} - t_{arrival\_k})}$$

Average Packet Call Throughput of user i from sector j

$$S_{user}(i, j) = \frac{\sum_{k=1}^{K} \frac{\text{\# bits in pkt call k}}{(t_{end\_k} - t_{arrival\_k})}}{K}$$

Figure A1. Throughput Statistic Description for System Simulations.

The service throughput for a given sector j is

$$ServiceSector(j) = \frac{1}{N_{seconds}} \sum_{k=1}^{N_{seconds}} \#\text{good bits for kth second inverval for sector j} \quad (1)$$

The service throughput averaged over all sectors in the system is

$$ServiceSystem = \frac{1}{N_{sectors}} \sum_{j=1}^{N_{sectors}} ServiceSector(j) \quad (2)$$

Also

$$ServiceSystem = \frac{\text{total good bits all sectors}}{N_{seconds} N_{sectors}} \quad (3)$$

or

$$ServiceSystem = \frac{\text{total good bits all sectors}}{(N_{good\_frames} + N_{retries} + N_{empty}) T_{frame}} \quad (4)$$

where

N_{good_frames} – total good frames over all sectors sent during simulation
$N_{retries}$ – total unsuccessful (“bad”) frames over all sectors transmitted during simulation
N_{empty} – total frame intervals over all sectors where there was no transmission during sim.
N_{lost} – total frame intervals over all sectors where the corresponding frame was aborted during sim.
T_{frame} – frame time interval

$$OTASystem = \frac{\text{total good bits all users}}{(N_{good\_frames} + N_{retries}) T_{frame}} \quad (5)$$

$$Utilization = \frac{N_{good\_frames} + N_{retries} + N_{lost}}{N_{good\_frames} + N_{retries} + N_{empty} + N_{lost}} \quad (6)$$

$$\frac{ServiceSystem}{OTASystem} = \frac{N_{good\_frames} + N_{retries}}{N_{good\_frames} + N_{retries} + N_{empty}} \quad (7)$$

Therefore

$$\boxed{Utilization \approx \frac{ServiceSystem}{OTASystem}} \quad (8)$$

The average packet call throughput is given by

$$PktCall(k,i,\ j) = \frac{\#\,\text{bits in pkt call k}}{(t_{end\_k} - t_{arrival\_k})} \tag{9}$$

where

$k =$ denotes the k^{th} packet call from a group of K packet calls

$i =$ denotes the i^{th} user from a group of N users

j = denotes the j^{th} drop from a group of J drops

the time parameters in Equation 10 are described in Figure A1.

The user packet call throughput becomes

$$UserPktCall(i,\ j) = \frac{1}{K}\sum_{k=1}^{K} PktCall(k,i,\ j) \tag{10}$$

ANNEX B

System Simulation Assumptions

The following parameters related to HSDPA features were used:

- MCS selection based on CPICH measurement (RSCP/ISCP)
- MCS update rate: once per TTI (e.g. 3.33 ms (5 slots))
- CPICH measurement transmission delay: 1 frame
- Selected MCS can be applied after 1 frame delay upon receiving measurement report
- Std. dev. of CPICH measurement error: 0
- CPICH measurement rate: once per TTI (sampling is 0.67ms, IIR filter sampled once per TTI using IIR filter with coefficient of 0.3 (new data weighted by 0.7))
- CPICH measurement report error rate: 0 %
- Frame length for fast HARQ: TTI length (3.33ms, 2.00ms, 0.67ms)
- Fast HARQ feedback error rate: 0%
- Channel Model: 3kph, single Rayleigh ray with 0.98 fraction of recovered power
- STTD enabled.
- Maximum C/I scheduler (see [2])
- Modified ETSI Call model (see [2])
- 0.5dB Eb/Nt reduction before mapping to Frame Erasure Look up Table.
- Throughput measurements are over the entire two-ring system and the center cell.

Basic system level parameters:
The basic system level simulation parameters are listed in Table B1 [2] below.

Table B1. Basic system level simulation assumptions.

Parameter	**Explanation/Assumption**	**Comments**
Cellular layout	Hexagonal grid, 3-sector sites	19 sites
Site to Site distance	2800 m	
Antenna pattern	As proposed in [4]	Only horizontal pattern specified
Propagation model	$L = 128.1 + 37.6\ Log_{10}(R)$	R in kilometres
CPICH power	-10 dB	
Other common channels	- 10 dB	
Power allocated to HSDPA transmission, including associated signaling	Max. 70% of total cell power	
Slow fading	Similar to UMTS 30.03, B 1.4.1.4	
Std. deviation of slow fading	8.0 dB	
Correlation between sectors	1.0	
Correlation between sites	0.5	
Correlation distance of slow fading	50 m	See D,4 in UMTS 30.03.
Carrier frequency	2000 MHz	
BS antenna gain	14 dB	
UE antenna gain	0 dBi	
UE noise figure	9 dB	
Max. # of retransmissions	15	Retransmissions by fast HARQ
Fast HARQ scheme	Chase combining	Dual stop-and-wait
BS total Tx power	42.3 dBm	
Active set size	3	Maximum size
Specify Fast Fading model	Jakes spectrum	Generated by Filter approach

Annex C
Aggregate Packet Call Throughput Definition

The aggregate packet call throughput for user *i* delivered by sector *j* is given by

$$S_{user}(i, j) = \frac{\sum_{k=1}^{K} \text{bits in pkt call k}}{\sum_{k=1}^{K} (t_{end\_k} - t_{arrival\_k})} \qquad \text{(c1)}$$

where

k = denotes the k^{th} packet call from a group of K packet calls

i = denotes the i^{th} user from a group of N users

$t_{arrival\_k}$ = first packet of packet call k arrives in queue

t_{end_k} = last packet of packet k is received by MS

Note for uncompleted packet calls, t_{end_k} is set to simulation end time.

The aggregate sector packet call throughput for sector j is given by

$$S_{sector}(j) = \frac{\sum_{i=1}^{N}\sum_{k=1}^{K} \text{bits in pkt call k of user i from sector j}}{\sum_{i=1}^{N}\sum_{k=1}^{K} (t_{end\_k,i} - t_{arrival\_k,i})} \qquad \text{(c2)}$$

The aggregate sector packet call throughput for cell site with Nsectors sectors is

$$S_{site} = \frac{\sum_{j=1}^{N_{sectors}}\sum_{i=1}^{N}\sum_{k=1}^{K} \text{bits in pkt call k of user i from sector j}}{\sum_{j=1}^{N_{sectors}}\sum_{i=1}^{N}\sum_{k=1}^{K} (t_{end\_k,i,j} - t_{arrival\_k,i,j})} \qquad \text{(c2)}$$