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Title: HSDPA System Performance with Variable TTI

Document for: Discussion and Decision

1 Introduction

Simulation results for the variable TTI proposal are presented along with simulations of a fixed TTI scheme.

2 Simulation Results

The MCS table used for the variable TTI scheme is shown in Table 1 and for the fixed TTI, the MCS table is shown in Table 2.

Table 1. Data rates for variable TTI (VTTI)

TTI [slots]	Data rate [Kb/s] (Modulation, Coding Rate)				
	7680 bits code block	5120 bits code block	3840 bits code block	2560 bits code block	1280 bits code block
15	768 (QPSK, 0.16)	512 (QPSK, 0.106)	384 (QPSK, 0.08)	256 (QPSK, 0.053)	128 (QPSK, 0.027)
5	2304 (QPSK, 0.48)	1536 (QPSK, 0.32)	1152 (QPSK, 0.24)	768 (QPSK, 0.16)	384 (QPSK, 0.08)
3	3840 (QPSK, 0.8)	2560 (QPSK, 0.53)	1920 (QPSK, 0.4)	1280 (QPSK, 0.27)	640 (QPSK, 0.13)
2	5760 (8PSK, 0.8)	3840 (QPSK, 0.8)	2880 (8PSK, 0.4)	1920 (QPSK, 0.4)	960 (QPSK, 0.2)
1	11520 (64QAM, 0.8)	7680 (16QAM, 0.8)	5760 (8PSK, 0.8)	3840 (QPSK, 0.8)	1920 (QPSK, 0.4)

Table 2: Data rates for fixed TTI scheme of 5-slots.

Data Rate (Kbps)	Bytes per TTI	Modulation	Coding Rate
2400	1000	QPSK	1/2
4800	2000	16QAM	1/2
7200	3000	16QAM	3/4
10800	4500	64QAM	3/4

The throughput metrics used viz. Over-The-Air (OTA) Throughput, Service Throughput and Packet Call Throughput are as defined in the TR (see [1]). In addition the cumulative distribution function (cdf) of the UE packet call throughput is also provided as a measure of quality of service. As used in the TR [1], we have assumed (assumptions in the TR on propagation and traffic model are listed in the Appendix of this document):

- 30% power used by overhead channels
- Single path Rayleigh fading with 3km/hr speed.
- Fractional Recovered Power (FRP) is 0.98

The following additional assumptions are made in obtaining the simulation results of

- No limit on maximum number of retries.
- Fast cell selection is not considered.
- Results do not count padding into the throughput (i.e. only information bits count towards throughput).
- Channel quality measurement and ACK/NACK feedback are error-free.
- The channel quality feedback delay is assumed to be 6 slots and the ACK/NACK delay is assumed to be 3 slots.
- Both the fixed TTI scheme and the variable TTI scheme use Chase combining and do not change MCS on retransmission.
- Maximum C/I scheduler is used for both schemes.
- The MCS in both the schemes is selected based on the channel conditions and the user buffer size (in order to minimise the frame fill inefficiency).

It is important to note that Internet packet sizes can vary a lot. Some traffic models (see [2]) have provided a distribution for the occurrence of these packet sizes and typically include four packet sizes: 1500 bytes, 576 bytes, 552 bytes and 40 bytes. Ref. [2] indicates the occurrence probabilities of these packet sizes to be 0.44, 0.13, 0.12 and 0.31 respectively. Another study [3] verified the fact that the Internet traffic is dominated by small packets with peaks at the common sizes of 44, 552, 576, and 1500 bytes. The small packets, 40-44 bytes in length, include TCP acknowledgement segments, TCP control segments such as SYN, FIN, and RST packets, and telnet packets carrying single characters (keystrokes of a telnet session).

Therefore, it is of importance to consider HSDPA throughput performance for smaller than 1500 byte packet sizes. As an illustrative example, the packet size of 576 bytes was simulated and the performance of fixed and variable TTI schemes was compared. For the simulations, the page size distribution was kept the same (see traffic model in Appendix) but packets were assumed to be segmented into units of 576 bytes rather than into 1500 byte units as done with previous simulation results.

Results from Table 3 and Table 4 indicate that the variable TTI scheme outperforms the fixed TTI scheme in terms of the average values of performance metrics. A comparison of packet call cdfs (a measure of quality of service achieved) for low, moderate and heavy loads is shown in Figure 1 - Figure 3 respectively. (The packet call cdfs measure the fraction of UEs with packet call throughput less than abscissa). At low loads, the variable TTI scheme can support about 22% more users, at moderate loads better than 34% and at high loads about 33% more users. The gains result from the fact that the fixed TTI scheme suffers from frame fill efficiency as it would have to transmit over 5 slots regardless of whether there is sufficient data to send over all those slots or not. In contrast, the variable TTI scheme will end up transmitting the same data over far fewer slots most of the time, thus freeing up slots to schedule other users. In the case of 1500 byte MTU size, the frame fill inefficiency with the fixed TTI scheme is not substantial and therefore, the two schemes perform similarly.

In practice, there will be a mix of packet sizes and the variable TTI scheme is tailored to match both the buffer backlog (select column in rate table) and the channel quality (select row in the rate table) appropriately. While code division multiplexing (CDM) of users in the fixed TTI scheme will help improve the frame-fill efficiency, it comes at the cost of requiring to signal the code space assigned per TTI and also, will not completely exploit multi-user diversity.

Table 3. Throughput performance of Fixed 5-slot (3.33ms) TTI and MTU size of 576 bytes.

Number of UEs	OTA [Kb/s]	Service Throughput [Kb/s]	Packet Call Throughput [Kb/s]	Utilization
12	1039.3	402.7	445.0	0.39
37	1303.5	1168.7	366.1	0.87
56	1523.6	1517.8	314.1	1.00
75	1723.8	1723.8	296.8	1.00
100	1908.1	1908.1	293.1	1.00

Table 4. Throughput performance of Variable TTI

Number of UEs	OTA [Kb/s]	Service Throughput [Kb/s]	Packet Call Throughput [Kb/s]	Utilization
12	1136.6	408.1	447.9	0.36
37	1408.2	1221.2	376.1	0.87
45	1514.2	1422.3	357.8	0.94
50	1602.2	1550.5	343.7	0.97
56	1705.3	1676.7	335.9	0.98
75	1968.8	1967.9	314.2	1.00
80	2015.8	2015.4	308.4	1.00
100	2235.1	2235.1	302.9	1.00
105	2286.4	2286.4	308.5	1.00
110	2320.0	2320.0	302.3	1.00

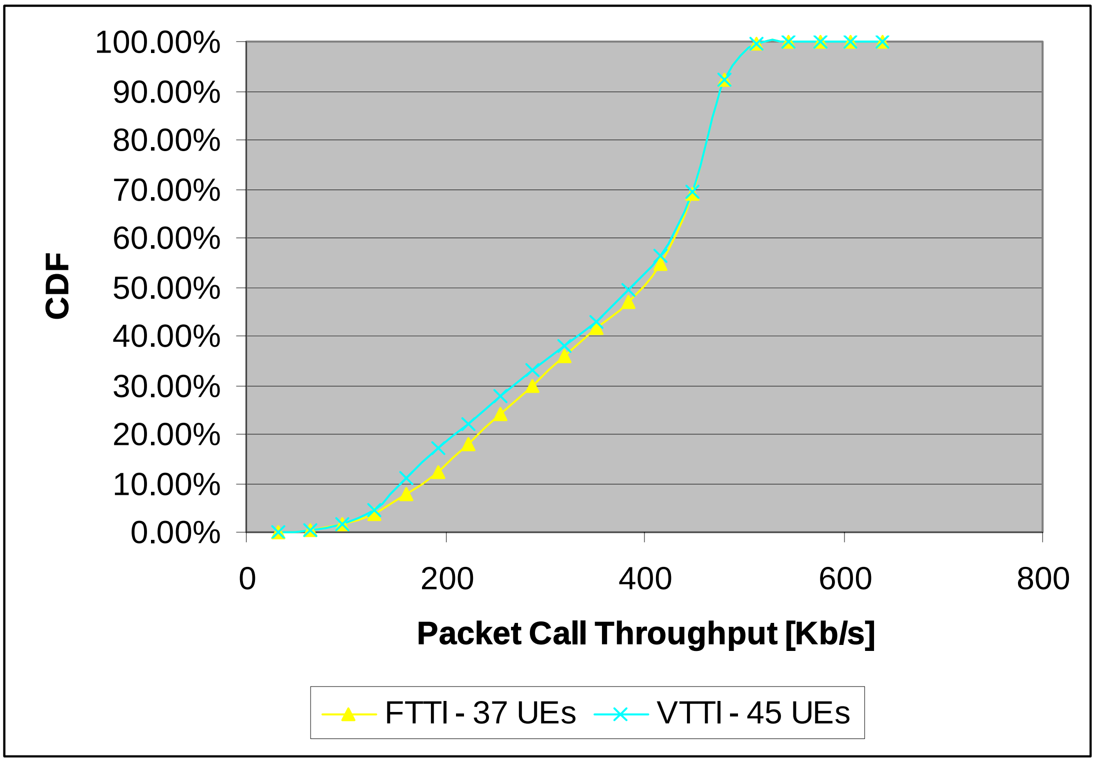

Figure 1. CDF of Packet Call Throughput. It measures the percentage of UEs with packet call throughput less than abscissa

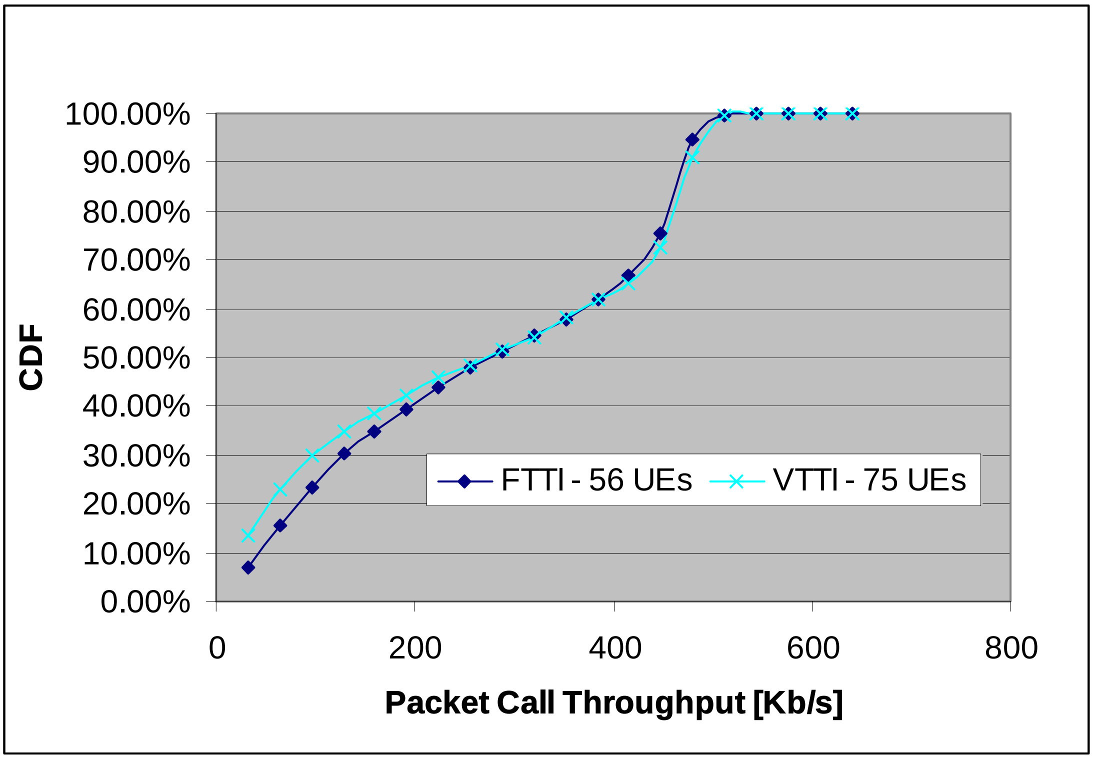

Figure 2. CDF of Packet Call Throughput

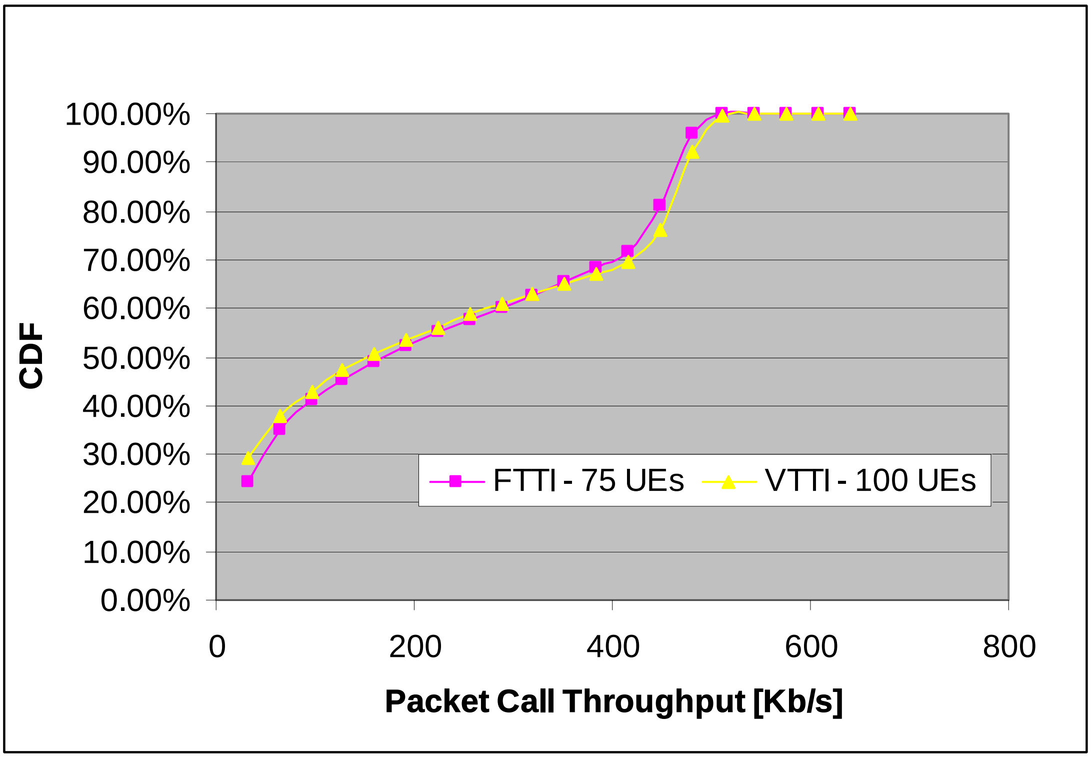

Figure 3. CDF of Packet Call Throughput

3 Signalling for Variable TTI

The signalling for variable TTI is discussed in [4] where it is proposed to indicate the TTI length on Downlink DPCCH. The TTI length along with the code block size indication is used to indicate the MCS used (see Table 1). Therefore, no explicit signalling is needed for indicating the MCS. A fixed TTI scheme needs explicit indication of the MCS (e.g., 3-bits) and the start and end codes (e.g., 10 bits for 32 SF codes) for the code multiplexed users. Therefore, the signalling overhead in a variable TTI scheme will be less compared to a fixed TTI scheme.

4 Summary of Performance Results

Number of UEs supported for the same quality of service (packet call throughput CDF)		Service Throughput [Kb/s]		Variable TTI Gain (Number of UEs, Service Throughput) [%]
Fixed 5-slot TTI	Variable TTI	Fixed 5-slot TTI	Variable TTI	
37	45	1256.7	1422.3	(22, 22)
56	75	1473.2	1968.8	(34, 30)
75	100	1657.4	2286.4	(33, 30)

Table 5. Performance Comparison of Fixed and Variable TTI schemes.

5 Conclusion and Recommendation

A system performance comparison of variable TTI and a fixed 5-slot (3.33ms) TTI is presented. The variable TTI approach provides 22-34% improvement in the number of UEs supported and 22-30% gain in system throughput for the same QoS (measured as packet call throughput CDF). These gains are based on using Chase combining for both methods. An open loop traffic model with MTU size of 576 bytes is considered in the simulations. With a closed loop traffic model the fixed TTI scheme will further suffer from the frame fill inefficiency and the difference in performance between the two schemes will even be larger.

The variable TTI scheme also has other benefits such as enabling adaptive operation when incremental redundancy (IR) is used instead of Chase combining. The signalling needed for variable TTI is no more compared to a fixed TTI scheme. It is therefore recommended that a variable TTI approach be adopted for HS-DSCH.

6 References

[1] "Physical Layer Aspects of UTRA High Speed Downlink Packet Access" TR25.848.

[2] A. Reyes-Lecuona et al, "A page-oriented WWW traffic model for wireless system simulations," *Proc. Of International Teletraffic Congress 16*, 1999.

[3] http://www.caida.org/outreach/papers/Nae/4hansen.html

[4] "Signalling and Timing Considerations for HS-DSCH", 12A010024, Lucent.

7 Annex: Simulation parameters

The system level simulation parameters are listed in Table 6 below

Table 6. Basic system level simulation assumptions.

Parameter	**Explanation/Assumption**	**Comments**
Cellular layout	Hexagonal grid, 3-sector sites	Provide your cell layout picture
Site to Site distance	2800 m	
Antenna pattern	As proposed in [2]	Only horizontal pattern specified
Propagation model	$L = 128.1 + 37.6\ Log_{10}(R)$	R in kilometers
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	As modeled in UMTS 30.03, B 1.4.1.4	
Std. deviation of slow fading	8 dB	
Correlation between sectors	1.0	
Correlation between sites	0.5	
Correlation distance of slow fading	50 m	
Carrier frequency	2000 MHz	
BS antenna gain	14 dB	
UE antenna gain	0 dBi	
UE noise figure	9 dB	
Max. # of retransmissions	Specify the value used	Retransmissions by fast HARQ
Fast HARQ scheme	Chase combining	
BS total Tx power	Up to 44 dBm	
Active set size	3	Maximum size
Frame duration	3.33 ms	
Scheduling	Max C/I	
Specify Fast Fading model	Jakes spectrum	Generated e.g. by Jakes or Filter approach

The fundamentals of the data-traffic model are captured in Table 7 below.

Table 7. Data-traffic model parameters

Process	Random Variable	Parameters
Packet Calls Size	Pareto with cutoff	A=1.1, k=4.5 Kbytes, m=2 Mbytes, μ = 25 Kbytes
Time Between Packet Calls	Geometric	μ = 5 seconds
Packet Size	Segmented based on MTU size	576 octets
Packets per Packet Call	Deterministic	Based on Packet Call Size and Packet MTU
Packet Inter-arrival Time (open- loop)	Geometric	6ms
Packet Inter-arrival Time (closed-loop)	Deterministic	TCP/IP Slow Start (Fixed Network Delay of 100 ms)