20.1 DOWNLINK BIT RATES

20.1.1 FDD

★ The Physical Downlink Shared Channel (PDSCH) is used to transfer application data. The throughput achieved by the PDSCH depends upon:

- the number of Resource Elements allocated to the PDSCH
- the modulation scheme applied to each Resource Element
- the quantity of redundancy included by physical layer processing
- the use of multiple antenna transmission schemes
- the use of Carrier Aggregation

★ The number of PDSCH Resource Elements depends upon the channel bandwidth and the choice between the normal and extended cyclic prefix. It also depends upon the overheads generated by the other physical channels and physical signals

★ The modulation scheme and quantity of redundancy depend upon the RF channel conditions. UE experiencing good channel conditions are more likely to be allocated higher order modulation schemes with less redundancy

★ Multiple antenna transmission schemes increase the throughput achieved by the PDSCH. 2×2 MIMO using antenna ports 0 and 1 approximately doubles the peak throughput whereas 4×4 MIMO using antenna ports 0, 1, 2 and 3 approximately quadruples the peak throughput. Cell specific Reference Signal overheads increase when using MIMO with antenna ports 0, 1, 2 and 3 so the throughputs are less than double and quadruple the single antenna case

★ The use of antenna ports 7 to 14 for 2×2 MIMO, 4×4 MIMO or 8×8 MIMO is discussed towards the end of this section. Likewise, the use of Carrier Aggregation is discussed towards the end of this section. The throughput figures in Table 220, Table 221 and Table 222 assume the use of antenna ports 0 to 3

★ The PDSCH is a shared channel so its throughput capability has to be shared between all users. Increasing the number of users reduces the throughput per user. Users experiencing poor channel conditions will reduce the total cell throughput

★ Table 220 presents a set of theoretical absolute maximum physical layer throughputs which could be achieved if all Resource Elements were allocated to the PDSCH and the physical layer did not add any redundancy. These figures are not achievable in practice but provide a starting point from which to derive the maximum expected throughputs

★ The non-MIMO throughputs in Table 220 have been generated by multiplying the modulation symbol rate by the number of bits per symbol. For example, the 20 MHz channel bandwidth has 100 Resource Blocks providing 1200 subcarriers in the frequency domain. When using the normal cyclic prefix there are 14 OFDMA symbols during each 1 ms subframe so the modulation symbol rate is given by 1200 × 14 / 0.001 = 16.8 Msps. The bit rate when using 64QAM is then given by 16.8 Msps × 6 bits per symbol = 100.8 Mbps

★ The MIMO throughputs in Table 220 have been generated by multiplying the 64QAM throughputs by the relevant MIMO rank, i.e. the throughputs have been doubled for 2×2 MIMO and quadrupled for 4×4 MIMO

	Channel Bandwidth	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
	Resource Blocks in the frequency domain	6	15	25	50	75	100
Normal Cyclic Prefix	OFDMA symbols per 1 ms	14					
	Modulation symbol rate (Msps)	1.0	2.5	4.2	8.4	12.6	16.8
	QPSK Bit Rate (Mbps)	2.0	5.0	8.4	16.8	25.2	33.6
	16QAM Bit Rate (Mbps)	4.0	10.1	16.8	33.6	50.4	67.2
	64QAM Bit Rate (Mbps)	6.1	15.1	25.2	50.4	75.6	100.8
	2×2 MIMO 64QAM Bit Rate (Mbps)	12.1	30.2	50.4	100.8	151.2	201.6
	4×4 MIMO 64QAM Bit Rate (Mbps)	24.2	60.5	100.8	201.6	302.4	403.2
Extended Cyclic Prefix	OFDMA symbols per 1 ms	12					
	Modulation symbol rate (Msps)	0.9	2.2	3.6	7.2	10.8	14.4
	QPSK Bit Rate (Mbps)	1.7	4.3	7.2	14.4	21.6	28.8
	16QAM Bit Rate (Mbps)	3.5	8.6	14.4	28.8	43.2	57.6
	64QAM Bit Rate (Mbps)	5.2	13.0	21.6	43.2	64.8	86.4
	2×2 MIMO 64QAM Bit Rate (Mbps)	10.4	25.9	43.2	86.4	129.6	172.8
	4×4 MIMO 64QAM Bit Rate (Mbps)	20.7	51.8	86.4	172.8	259.2	345.6

Table 220 – Absolute maximum FDD physical layer throughputs if all Resource Elements were allocated to the PDSCH

★ The first step in deriving the maximum expected throughput is to remove the overheads generated by the other physical channels and physical signals, i.e. the PCFICH, PDCCH, PHICH, PBCH, Primary and Secondary Synchronisation Signals, and the Cell Specific Reference Signal. Table 221 presents a set of maximum physical layer throughputs with these overheads removed. The results still assume a coding rate of 1, i.e. the physical layer has not introduced any redundancy

★ Table 221 illustrates the relatively significant impact of the number of OFDMA symbols allocated to the PDCCH, PCFICH and PHICH. These physical channels can be allocated 2, 3 or 4 symbols when using the 1.4 MHz channel bandwidth, and 1, 2 or 3 symbols when using the other channel bandwidths

		Channel Bandwidth	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Normal Cyclic Prefix	1 PDCCH Sym.	QPSK Bit Rate (Mbps)	-	4.4	7.4	14.9	22.4	29.9
		16QAM Bit Rate (Mbps)	-	8.8	14.8	29.8	44.8	59.8
		64QAM Bit Rate (Mbps)	-	13.2	22.2	44.7	67.1	89.7
		2×2 MIMO 64QAM Bit Rate (Mbps)	-	25.3	42.5	85.8	129.0	172.2
		4×4 MIMO 64QAM Bit Rate (Mbps)	-	47.7	80.3	161.9	243.4	325.0
	2 PDCCH Sym.	QPSK Bit Rate (Mbps)	1.5	4.0	6.8	13.7	20.6	27.5
		16QAM Bit Rate (Mbps)	3.1	8.1	13.6	27.4	41.2	55.0
		64QAM Bit Rate (Mbps)	4.6	12.1	20.4	41.1	61.8	82.5
		2×2 MIMO 64QAM Bit Rate (Mbps)	8.8	23.1	39.0	78.5	118.1	157.7
		4×4 MIMO 64QAM Bit Rate (Mbps)	17.2	44.8	75.5	152.4	229.2	306.0
	3 PDCCH Sym.	QPSK Bit Rate (Mbps)	1.4	3.7	6.2	12.5	18.8	25.1
		16QAM Bit Rate (Mbps)	2.8	7.3	12.4	25.0	37.6	50.2
		64QAM Bit Rate (Mbps)	4.2	11.0	18.6	37.4	56.4	75.3
		2×2 MIMO 64QAM Bit Rate (Mbps)	8.0	20.9	35.3	71.4	107.4	143.3
		4×4 MIMO 64QAM Bit Rate (Mbps)	15.4	40.5	68.3	137.9	207.4	277.0
	4 PDCCH Sym.	QPSK Bit Rate (Mbps)	1.3	-	-	-	-	-
		16QAM Bit Rate (Mbps)	2.5	-	-	-	-	-
		64QAM Bit Rate (Mbps)	3.8	-	-	-	-	-
		2×2 MIMO 64QAM Bit Rate (Mbps)	7.1	-	-	-	-	-
		4×4 MIMO 64QAM Bit Rate (Mbps)	13.7	-	-	-	-	-
Extended Cyclic Prefix	1 PDCCH Sym.	QPSK Bit Rate (Mbps)	-	3.7	6.2	12.5	18.8	25.1
		16QAM Bit Rate (Mbps)	-	7.3	12.4	25.0	37.6	50.2
		64QAM Bit Rate (Mbps)	-	11.0	18.6	37.5	56.4	75.3
		2×2 MIMO 64QAM Bit Rate (Mbps)	-	21.0	35.4	71.4	107.3	143.4
		4×4 MIMO 64QAM Bit Rate (Mbps)	-	39.1	66.0	133.2	200.4	267.5
	2 PDCCH Sym.	QPSK Bit Rate (Mbps)	1.3	3.3	5.6	11.3	17.0	22.7
		16QAM Bit Rate (Mbps)	2.5	6.6	11.2	22.6	34.0	45.4
		64QAM Bit Rate (Mbps)	3.8	9.9	16.8	33.9	51.0	68.1
		2×2 MIMO 64QAM Bit Rate (Mbps)	7.1	18.8	31.8	64.2	96.6	128.9
		4×4 MIMO 64QAM Bit Rate (Mbps)	13.8	36.2	61.2	123.6	186.1	248.5
	3 PDCCH Sym.	QPSK Bit Rate (Mbps)	1.1	3.0	5.0	10.1	15.2	20.3
		16QAM Bit Rate (Mbps)	2.2	5.9	10.0	20.2	30.4	40.6
		64QAM Bit Rate (Mbps)	3.3	8.9	15.0	30.3	45.6	60.9
		2×2 MIMO 64QAM Bit Rate (Mbps)	6.3	16.6	28.2	56.9	85.8	114.6
		4×4 MIMO 64QAM Bit Rate (Mbps)	12.0	31.9	54.0	109.2	164.3	219.5
	4 PDCCH Sym.	QPSK Bit Rate (Mbps)	1.0	-	-	-	-	-
		16QAM Bit Rate (Mbps)	2.0	-	-	-	-	-
		64QAM Bit Rate (Mbps)	3.0	-	-	-	-	-
		2×2 MIMO 64QAM Bit Rate (Mbps)	5.7	-	-	-	-	-
		4×4 MIMO 64QAM Bit Rate (Mbps)	10.9	-	-	-	-	-

Table 221 – Maximum FDD physical layer throughputs based upon Resource Elements available to the PDSCH (coding rate = 1, no retransmissions, no SRB, paging nor SIB overheads, no protocol stack overheads)

★ In practice, the number of symbols allocated to the PCFICH, PDCCH and PHICH depends upon the quantity of traffic loading the cell. There will be a requirement for an increased number of symbols as the quantity of traffic increases, i.e. the maximum throughput capability will decrease as the traffic and associated overheads increase

★ The figures in Table 221 are significantly less than those in Table 220. For example, the maximum throughput associated with the 20 MHz channel bandwidth, the normal cyclic prefix and 4×4 MIMO decreases from 403 Mbps to 325, 306 or 277 Mbps (depending upon the number of symbols allocated to the PDCCH, PCFICH and PHICH). This demonstrates the impact of the overheads generated by the physical channels and physical signals which do not transfer any application data

★ Redundancy added by the physical layer further reduces the throughputs measured at the top of the physical layer. The PDSCH uses a combination of rate 1/3 Turbo coding and rate matching to generate redundancy. In general, the quantity of redundancy is large when UE experience poor channel conditions and small when UE experience good channel conditions

★ Figure 192 illustrates an example link adaptation strategy which defines the physical layer coding rate as a function of the channel conditions and modulation scheme. The coding rate reflects the quantity of redundancy added by the physical layer. A low coding rate indicates a large quantity of redundancy while a high coding rate reflects a small quantity of redundancy. A coding rate of 1 corresponds to no redundancy

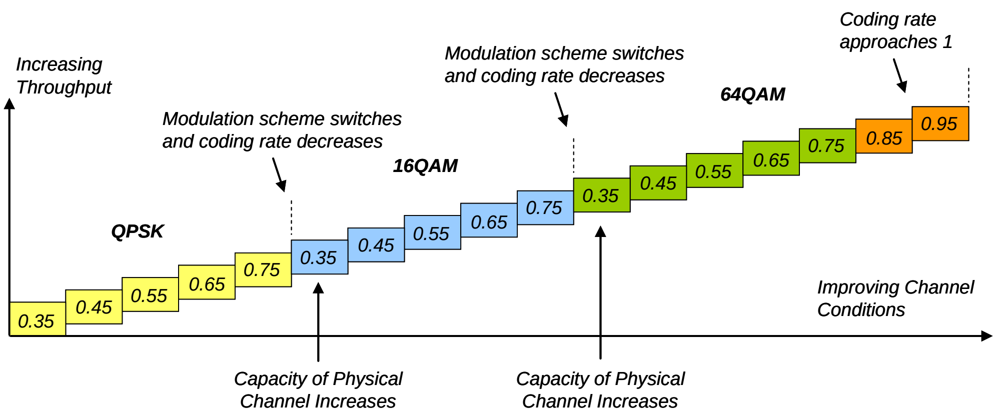

Figure 192 – Physical layer coding rate as a function of channel conditions and modulation scheme

★ QPSK and a low coding rate are associated with poor channel conditions. Link adaptation allocates larger transport block sizes as the channel conditions improve but the modulation scheme is kept as QPSK. This forces the quantity of redundancy to decrease (and the coding rate to increase), i.e. larger quantities of data are transferred without increasing the capacity of the physical channel

★ In this example, the modulation scheme is switched from QPSK to 16QAM once the channel conditions have improved sufficiently to allow the coding rate to increase to 0.75. Switching the modulation scheme increases the capacity of the physical channel so the quantity of redundancy can be increased. Link adaptation then continues to allocate larger transport block sizes as the channel conditions improve. The modulation scheme is switched from 16QAM to 64QAM once the channel conditions have improved enough to allow the coding rate to again reach 0.75

★ Once 64QAM has been allocated, link adaptation continues to allocate larger transport block sizes as the channel conditions improve. In this case, there is no option to switch to a higher order modulation scheme once the coding rate reaches 0.75. Instead, link adaptation continues to allocate larger transport block sizes and the coding rate approaches 1

★ System Information Blocks (SIB), paging messages and RRC signalling are transferred using the PDSCH. This reduces the PDSCH capacity available for application data. The overhead generated by the SIB, paging messages and RRC signalling will depend upon the quantity of traffic loading the cell but is likely to be relatively small, i.e. less than 100 kbps

★ Retransmissions reduce the higher layer throughputs. Hybrid Automatic Repeat Request (HARQ) retransmissions from the MAC layer reduce the throughputs measured from above the MAC layer. Automatic Repeat Request (ARQ) retransmissions from the RLC layer reduce the throughputs measured from above the RLC layer. Likewise TCP retransmissions reduce the throughput measured from above the TCP layer

★ Protocol stack headers also reduce the higher layer throughputs. The MAC, RLC, PDCP and IP layers add headers to the application data. The PDCP layer provides header compression for IP data streams so is able to reduce the impact of the IP header. The TCP and UDP layers also add their own headers when using TCP or UDP applications

★ Table 222 presents a set of example application throughputs assuming physical layer coding rates of 0.75 and 0.95. The coding rate of 0.95 is only shown for the 64QAM modulation scheme to remain consistent with the link adaptation strategy shown in Figure 192. Table 222 assumes the normal cyclic prefix, a 10 % retransmission rate and an additional 5 % overhead generated by a combination of the SIB, paging, RRC signalling and protocol stack headers

★ These throughput figures are comparable to those provided by UMTS High Speed Packet Access (HSPA) when making similar assumptions for both technologies. For example, UMTS HSPA with a 5 MHz channel bandwidth and 64QAM can achieve an application layer throughput of approximately 18 Mbps. LTE offers the same throughput capability when using 5 MHz and 64QAM if a single OFDMA symbol is allocated to the PDCCH, PCFICH and PHICH. Similar comparisons can be made when MIMO is applied to HSPA, and when HSPA is allocated 2 or 4 RF carriers to generate effective UMTS channel bandwidths of 10 or 20 MHz

		Coding Rate	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
1 PDCCH Symbol	QPSK Bit Rate (Mbps)	0.75	-	2.8	4.7	9.6	14.4	19.2
	16QAM Bit Rate (Mbps)	0.75	-	5.6	9.5	19.1	28.7	38.3
	64QAM Bit Rate (Mbps)	0.75	-	8.5	14.2	28.7	43.0	57.5
		0.95	-	10.7	18.0	36.3	54.5	72.9
	2×2 MIMO 64QAM Bit Rate (Mbps)	0.75	-	16.2	27.3	55.0	82.7	110.4
		0.95	-	20.5	34.5	69.7	104.8	139.9
	4×4 MIMO 64QAM Bit Rate (Mbps)	0.75	-	30.6	51.5	103.8	156.1	208.4
		0.95	-	38.7	65.2	131.5	197.7	264.0
2 PDCCH Symbols	QPSK Bit Rate (Mbps)	0.75	1.0	2.6	4.4	8.8	13.2	17.6
	16QAM Bit Rate (Mbps)	0.75	2.0	5.2	8.7	17.6	26.4	35.3
	64QAM Bit Rate (Mbps)	0.75	2.9	7.8	13.1	26.4	39.6	52.9
		0.95	3.7	9.8	16.6	33.4	50.2	67.0
	2×2 MIMO 64QAM Bit Rate (Mbps)	0.75	5.6	14.8	25.0	50.3	75.7	101.1
		0.95	7.1	18.8	31.7	63.8	95.9	128.1
	4×4 MIMO 64QAM Bit Rate (Mbps)	0.75	11.0	28.7	48.4	97.7	147.0	196.2
		0.95	14.0	36.4	61.3	123.8	186.2	248.5
3 PDCCH Symbols	QPSK Bit Rate (Mbps)	0.75	0.9	2.4	4.0	8.0	12.1	16.1
	16QAM Bit Rate (Mbps)	0.75	1.8	4.7	8.0	16.0	24.1	32.2
	64QAM Bit Rate (Mbps)	0.75	2.7	7.1	11.9	24.0	36.2	48.3
		0.95	3.4	8.9	15.1	30.4	45.8	61.2
	2×2 MIMO 64QAM Bit Rate (Mbps)	0.75	5.1	13.4	22.6	45.8	68.9	91.9
		0.95	6.5	17.0	28.7	58.0	87.2	116.4
	4×4 MIMO 64QAM Bit Rate (Mbps)	0.75	9.9	26.0	43.8	88.4	133.0	177.6
		0.95	12.5	32.9	55.5	112.0	168.5	225.0
4 PDCCH Symbols	QPSK Bit Rate (Mbps)	0.75	0.8	-	-	-	-	-
	16QAM Bit Rate (Mbps)	0.75	1.6	-	-	-	-	-
	64QAM Bit Rate (Mbps)	0.75	2.4	-	-	-	-	-
		0.95	3.1	-	-	-	-	-
	2×2 MIMO 64QAM Bit Rate (Mbps)	0.75	4.6	-	-	-	-	-
		0.95	5.8	-	-	-	-	-
	4×4 MIMO 64QAM Bit Rate (Mbps)	0.75	8.8	-	-	-	-	-
		0.95	11.1	-	-	-	-	-

Table 222 – FDD application layer throughputs based upon Resource Elements available to the PDSCH (normal cyclic prefix, 10% retransmissions, 5% additional overheads)

- ★ Reference Signal overheads change for the release 10 version of the 3GPP specifications when using antenna ports 7 to 14 for 2×2 MIMO, 4×4 MIMO or 8×8 MIMO. In these cases, the cell specific Reference Signal can be transmitted on antenna port 0, while the PDSCH and UE specific Reference Signals are transmitted on antenna ports 7 to 14, and CSI Reference Signals are transmitted on antenna ports 15 to 22. In addition, some subframes can be configured as MBSFN subframes. This allows transmission of the PDSCH to 3GPP release 10, and newer devices while avoiding the requirement to transmit the cell specific Reference Signal. These subframes are known as ‘LTE Advanced’ subframes. Configuring them as MBSFN subframes is a workaround solution to avoid older devices from expecting to receive the cell specific Reference Signal (MBSFN data is not actually transmitted during those subframes)
- ★ 3GPP TR 36.912 specifies an LTE Advanced peak spectral efficiency of 30.6 bps/Hz when using 8×8 MIMO with FDD. This figure is calculated as follows:
  - o total number of Resource Elements per antenna port within a 10 ms radio frame when using the normal cyclic prefix and the 20 MHz channel bandwidth is given by 12 × 14 × 100 × 10 = 168 000 Resource Elements
  - o accounting for 8 antenna ports increases the total number of Resource Elements to 8 × 168 000 = 1 344 000 Resource Elements
  - o assuming that the PCFICH, PDCCH and PHICH occupy only the first OFDMA symbol within each subframe generates an overhead of 1 / 14 = 7.14 % (normal cyclic prefix is used)

- o assuming that the cell specific Reference Signal is only transmitted on antenna port 0, and assuming that 6 subframes within the radio frame are configured as MBSFN subframes then it is only necessary to transfer cell specific Reference Signals on antenna port 0 during the remaining 4 subframes. The overhead generated by the cell specific Reference Signal transmissions outside the first OFDMA symbol is then given by 6 × 100 × 4 / 168 000 = 1.43 % (the overhead generated by cell specific Reference Signal transmissions during the first OFDMA symbol has already been captured within the PCFICH, PDCCH and PHICH overhead calculation)
- o assuming that the UE specific Reference Signal occupies 24 Resource Elements per Resource Block pair, then the corresponding overhead is given by 24 / (12 × 14) = 14.29 %
- o assuming that the CSI Reference Signal is transmitted with a periodicity of 10 ms then the corresponding overhead for 8 antenna ports is given by (2 × 8) / (12 × 14 × 10) = 0.95 % (at the time of writing 3GPP TR 36.912 it was assumed that there would be 2 Resource Elements per antenna port for the CSI Reference Signal. The subsequent standardisation process resulted in the use of code division multiplexing so a total of 8 rather than 16 Resource Elements are required for transmission on 8 antenna ports – see Figure 90 in section 5.2.5. This halves the actual overhead generated by the CSI Reference Signal)
- o assuming that the PBCH and Synchronisation Signals occupy 564 Resource Elements per radio frame, then the corresponding overhead is given by 564 / 168 000 = 0.34 %
- o summing the set of overheads generates a total overhead of (7.14 + 1.43 + 14.29 + 0.95 + 0.34) = 24.15 %
- o this overhead reduces the number of Resource Elements available to the PDSCH to 1 344 000 × (1 – 0.2415) = 1 019 424 Resource Elements. Assuming that 64QAM is applied to each Resource Element generates a physical layer throughput which is given by (1 019 424 × 6) / 0.010 = 611.654 Mbps
- o the spectral efficiency is then obtained after dividing by the channel bandwidth of 20 MHz, i.e. (611.654 / 20) = 30.6 bps/Hz

★ In practice, the spectral efficiency will be less than 30.6 bps/Hz if more than a single OFDMA symbol is allocated to the PCFICH, PDCCH and PHICH, or if subframes are not configured as MBSFN subframes for PDSCH transmission to release 10 or newer devices

★ Table 223 presents a set of theoretical absolute maximum physical layer throughputs for a selection of LTE Advanced scenarios including both 8×8 MIMO and Carrier Aggregation. These throughputs are the equivalent of those presented in Table 220. They assume that all Resource Elements are allocated to the PDSCH and that the physical layer does not add any redundancy. These figures are not achievable in practice but provide a starting point from which to derive the maximum expected throughputs

★ Figures are only presented for the normal cyclic prefix because the UE specific Reference Signal is not supported on antenna ports 9 to 14 when using the extended cyclic prefix. The scenarios presented in Table 223 assume that the PDSCH is transmitted on antenna ports 7 to 10 when using 4×4 MIMO, and on antenna ports 7 to 14 when using 8×8 MIMO

	Channel Bandwidth	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
	Resource Blocks in the frequency domain	6	15	25	50	75	100
Normal Cyclic Prefix	4×4 MIMO 64QAM Bit Rate (Mbps)	24.2	60.5	100.8	201.6	302.4	403.2
	8×8 MIMO 64QAM Bit Rate (Mbps)	48.4	121.0	201.6	403.2	604.8	806.4
	8×8 MIMO 64QAM, 2 Component Carriers Bit Rate (Mbps)	96.8	241.9	403.2	806.4	1209.6	1612.8
	8×8 MIMO 64QAM, 5 Component Carriers Bit Rate (Mbps)	241.9	604.8	1008.0	2016.0	3024.0	4032.0

Table 223 – Absolute maximum FDD physical layer throughputs if all Resource Elements were allocated to the PDSCH (LTE Advanced)

★ Deriving the maximum expected throughput requires the overheads generated by the other physical channels and physical signals to be taken into account. The following assumptions are made for this analysis:

- o the PCFICH, PDCCH and PHICH occupy either 1, 2, 3 or 4 OFDMA symbols per subframe (see section 6.2)
- o the cell specific Reference Signal is only transmitted from antenna port 0 (see section 5.2.1)
- o no MBSFN subframes are configured so the cell specific Reference Signal is transmitted during all subframes
- o the UE specific Reference Signal occupies 24 Resource Elements within each Resource Block pair (see section 5.2.3)
- o in the case of 4×4 MIMO, the CSI Reference Signal occupies 4 Resource Elements within each Resource Block pair, during subframes that include CSI Reference Signal transmissions. The CSI Reference Signal periodicity is assumed to be 10 ms (see section 5.2.5)
- o in the case of 8×8 MIMO, the CSI Reference Signal occupies 8 Resource Elements within each Resource Block pair, during subframes that include CSI Reference Signal transmissions. The CSI Reference Signal periodicity is assumed to be 10 ms (see section 5.2.5)
- o the PBCH and Synchronisation Signals occupy a total of 564 Resource Elements per radio frame (see sections 6.1 and 5.1)

★ These assumptions lead to the physical layer throughputs presented in Table 224. These throughputs do not yet account for the redundancy added by the physical layer. Nor do they account for the overheads generated by the various protocol stack headers and retransmissions. Nor do they account for the overheads generated by RRC signalling

	Channel Bandwidth	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
1 PDCCH Sym.	4×4 MIMO 64QAM Bit Rate (Mbps)	-	44.2	74.4	149.7	225.1	300.4
	8×8 MIMO 64QAM Bit Rate (Mbps)	-	88.1	148.2	298.5	448.7	598.9
	8×8 MIMO 64QAM Bit Rate, 2 Component Carriers (Mbps)	-	176.3	296.5	597.0	897.4	1197.9
	8×8 MIMO 64QAM Bit Rate, 5 Component Carriers (Mbps)	-	440.7	741.1	1492.4	2243.6	2994.7
2 PDCCH Sym.	4×4 MIMO 64QAM Bit Rate (Mbps)	15.3	39.9	67.2	135.3	203.5	271.6
	8×8 MIMO 64QAM Bit Rate (Mbps)	30.6	79.5	133.8	269.7	405.5	541.3
	8×8 MIMO 64QAM Bit Rate, 2 Component Carriers (Mbps)	61.2	159.0	267.7	539.4	811.0	1082.7
	8×8 MIMO 64QAM Bit Rate, 5 Component Carriers (Mbps)	152.9	397.5	669.1	1348.4	2027.6	2706.7
3 PDCCH Sym.	4×4 MIMO 64QAM Bit Rate (Mbps)	13.6	35.6	60.0	120.9	181.9	242.8
	8×8 MIMO 64QAM Bit Rate (Mbps)	27.1	70.9	119.4	240.9	362.3	483.7
	8×8 MIMO 64QAM Bit Rate, 2 Component Carriers (Mbps)	54.3	141.7	238.9	481.8	724.6	967.5
	8×8 MIMO 64QAM Bit Rate, 5 Component Carriers (Mbps)	135.6	354.3	597.1	1204.4	1811.6	2418.7
4 PDCCH Sym.	4×4 MIMO 64QAM Bit Rate (Mbps)	11.9	-	-	-	-	-
	8×8 MIMO 64QAM Bit Rate (Mbps)	23.7	-	-	-	-	-
	8×8 MIMO 64QAM Bit Rate, 2 Component Carriers (Mbps)	47.3	-	-	-	-	-
	8×8 MIMO 64QAM Bit Rate, 5 Component Carriers (Mbps)	118.4	-	-	-	-	-

Table 224 – Maximum FDD physical layer throughputs based upon Resource Elements available to the PDSCH (LTE Advanced) (coding rate = 1, no retransmissions, no SRB, paging nor SIB overheads, no protocol stack overheads)

★ Table 224 illustrates the relatively significant impact of the number of OFDMA symbols allocated to the PDCCH, PCFICH and PHICH. These physical channels can be allocated 2, 3 or 4 symbols when using the 1.4 MHz channel bandwidth, and 1, 2 or 3 symbols when using the other channel bandwidths

★ The 4×4 MIMO throughputs in Table 224 can be compared with those in Table 221. The 'LTE Advanced' throughputs for 4×4 MIMO (using antenna ports 7 to 10) are less than those based upon the release 8 and 9 versions of the specifications (using antenna ports 0 to 3). This is a result of the relative overheads generated by the cell specific Reference Signal and UE specific Reference Signal

  o when using 4×4 MIMO with antenna ports 0 to 3, the cell specific Reference Signal occupies 16 Resource Elements per Resource Block pair (assuming 2 or more OFDMA symbols are allocated to the PCFICH, PDCCH and PHICH, and counting only the Resource Elements outside those OFDMA symbols)

  o when using 4×4 MIMO with antenna ports 7 to 10, the cell specific Reference Signal occupies 6 Resource Elements per Resource Block pair, while the UE specific Reference Signal occupies 24 Resource Elements per Resource Block pair, i.e. a total of 30 Resource Elements are used outside the OFDMA symbols used for the PCFICH, PDCCH and PHICH (ignoring the relatively small impact of the CSI Reference Signal for the purposes this comparison)

★ These figures illustrate that there is an increased overhead when using antenna ports 7 to 10 for 4×4 MIMO. This overhead could be reduced if subframes were configured as MBSFN subframes. This would remove the requirement to transmit the cell specific Reference Signal so the overhead would reduce from 30 to 24 Resource Elements when using antenna ports 7 to 10. Nevertheless, the overhead remains greater than the 16 Resource Elements when using antenna ports 0 to 3

★ The throughputs shown in Table 224 increase in direct proportion to the number of Component Carriers because it is assumed that each Component Carrier has the same configuration. This does not have to be the case in practice, e.g. one Component Carrier could have 2 OFDMA symbols reserved for the PCFICH, PDCCH and PHICH, while another Component Carrier could have 3 OFDMA symbols reserved

★ The figures in Table 224 are significantly less than those in Table 223. For example, the maximum throughput associated with the 20 MHz channel bandwidth and 8×8 MIMO with 5 Component Carriers decreases from 4032 Mbps to 2994.7, 2706.7 or 2418.7 Mbps (depending upon the number of symbols allocated to the PDCCH, PCFICH and PHICH). This demonstrates the impact of the overheads generated by the physical channels and physical signals which do not transfer any application data

★ Table 225 presents a set of example application throughputs assuming physical layer coding rates of 0.75 and 0.95, as well as a 10 % retransmission rate and an additional 5 % overhead generated by a combination of the SIB, paging, RRC signalling and protocol stack headers

★ The maximum throughput generated by 8×8 MIMO with 5 Component Carriers is 2432.5 Mbps. This is obtained when assuming a single OFDMA symbol is used for the PCFICH, PDCCH and PHICH. The figure decreases to 1964.6 Mbps when assuming 3 OFDMA symbols are used for the PCFICH, PDCCH and PHICH. These throughput figures are high but require 100 MHz of spectrum. The equivalent figures for 40 MHz of spectrum are 973.0 and 785.8 Mbps

★ These throughput figures are peak connection throughputs rather than average cell throughputs. They assume that the UE is benefiting from 64QAM and full rank MIMO transmission while being scheduled resources on all Component Carriers

		Coding Rate	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
1 PDCCH Symbol	4×4 MIMO 64QAM Bit Rate (Mbps)	0.75	-	28.4	47.7	96.0	144.3	192.7
		0.95	-	35.9	60.4	121.6	182.8	244.0
	8×8 MIMO 64QAM Bit Rate (Mbps)	0.75	-	56.5	95.1	191.4	287.7	384.1
		0.95	-	71.6	120.4	242.4	364.5	486.5
	8×8 MIMO 64QAM, 2 Component Carriers Bit Rate (Mbps)	0.75	-	113.0	190.1	382.8	575.5	768.1
		0.95	-	143.2	240.8	484.9	728.9	973.0
	8×8 MIMO 64QAM, 5 Component Carriers Bit Rate (Mbps)	0.75	-	282.6	475.3	957.0	1438.7	1920.4
		0.95	-	357.9	602.0	1212.2	1822.3	2432.5
2 PDCCH Symbols	4×4 MIMO 64QAM Bit Rate (Mbps)	0.75	9.8	25.6	43.1	86.8	130.5	174.2
		0.95	12.5	32.4	54.5	109.9	165.3	220.6
	8×8 MIMO 64QAM Bit Rate (Mbps)	0.75	19.6	51.0	85.8	172.9	260.0	347.1
		0.95	24.8	64.6	108.7	219.0	329.4	439.7
	8×8 MIMO 64QAM, 2 Component Carriers Bit Rate (Mbps)	0.75	39.2	102.0	171.6	345.9	520.1	694.3
		0.95	49.7	129.1	217.4	438.1	658.8	879.4
	8×8 MIMO 64QAM, 5 Component Carriers Bit Rate (Mbps)	0.75	98.1	254.9	429.1	864.7	1300.2	1735.7
		0.95	124.2	322.8	543.5	1095.2	1646.9	2198.5
3 PDCCH Symbols	4×4 MIMO 64QAM Bit Rate (Mbps)	0.75	8.7	22.8	38.4	77.5	116.6	155.7
		0.95	11.1	28.9	48.7	98.2	147.7	197.2
	8×8 MIMO 64QAM Bit Rate (Mbps)	0.75	17.4	45.4	76.6	154.5	232.3	310.2
		0.95	22.0	57.6	97.0	195.7	294.3	392.9
	8×8 MIMO 64QAM, 2 Component Carriers Bit Rate (Mbps)	0.75	34.8	90.9	153.2	308.9	464.7	620.4
		0.95	44.1	115.1	194.0	391.3	588.6	785.8
	8×8 MIMO 64QAM, 5 Component Carriers Bit Rate (Mbps)	0.75	87.0	227.2	382.9	772.3	1161.7	1551.0
		0.95	110.2	287.8	485.0	978.3	1471.4	1964.6
4 PDCCH Symbols	4×4 MIMO 64QAM Bit Rate (Mbps)	0.75	7.6	-	-	-	-	-
		0.95	9.7	-	-	-	-	-
	8×8 MIMO 64QAM Bit Rate (Mbps)	0.75	15.2	-	-	-	-	-
		0.95	19.2	-	-	-	-	-
	8×8 MIMO 64QAM, 2 Component Carriers Bit Rate (Mbps)	0.75	30.4	-	-	-	-	-
		0.95	38.5	-	-	-	-	-
	8×8 MIMO 64QAM, 5 Component Carriers Bit Rate (Mbps)	0.75	75.9	-	-	-	-	-
		0.95	96.1	-	-	-	-	-

Table 225 – FDD application layer throughputs based upon Resource Elements available to the PDSCH (LTE Advanced) (10% retransmissions, 5% additional overheads)

★ 3GPP References: TS 36.211, TR 36.912