IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS

SWIRLATE IP LLC, Plaintiff, v. **RAB LIGHTING INC.,** Defendant.	C.A. No. 1:22-cv-06660 **JURY TRIAL DEMANDED** **PATENT CASE**

ORIGINAL COMPLAINT FOR PATENT INFRINGEMENT

Plaintiff Swirlate IP LLC files this Original Complaint for Patent Infringement against RAB Lighting Inc. and would respectfully show the Court as follows:

I. THE PARTIES

1. Plaintiff Swirlate IP LLC ("Swirlate" or "Plaintiff") is a Texas limited liability company having an address at 6009 W Parker Rd, Ste 149 – 1090, Plano, TX 75093-8121.

2. On information and belief, Defendant RAB Lighting Inc. ("Defendant") is a corporation with places of business at 1731 Wall St., Suite 200 Mount Prospect, IL 60056, and registered agent, Cogency Global Inc., at 600 South Second St., Suite 404 Springfield, IL 62704.

II. JURISDICTION AND VENUE

3. This action arises under the patent laws of the United States, Title 35 of the United States Code. This Court has subject matter jurisdiction of such action under 28 U.S.C. §§ 1331 and 1338(a).

4. On information and belief, Defendant is subject to this Court's specific and general personal jurisdiction, pursuant to due process and the Illinois Long-Arm Statute, due at least to its business in this forum, including at least a portion of the infringements alleged herein at 1731 Wall St, Suite 200 Mount Prospect, IL 60056.

5. Without limitation, on information and belief, Defendant has derived revenues from its infringing acts occurring within Illinois. Further, on information and belief, Defendant is subject to the Court's general jurisdiction, including from regularly doing or soliciting business, engaging in other persistent courses of conduct, and deriving substantial revenue from goods and services provided to persons or entities in Illinois. Defendant has committed such purposeful acts and/or transactions in Illinois such that it reasonably should know and expect that it could be haled into this Court as a consequence of such activity.

6. Venue is proper in this district under 28 U.S.C. § 1400(b). On information and belief, Defendant maintains places of business at 1731 Wall St, Suite 200 Mount Prospect, IL 60056. On information and belief, from and within this District Defendant has committed at least a portion of the infringements at issue in this case.

7. For these reasons, personal jurisdiction exists and venue is proper in this Court under 28 U.S.C. § 1400(b).

III. COUNT I
(PATENT INFRINGEMENT OF UNITED STATES PATENT NO. 7,154,961)

8. Plaintiff incorporates the above paragraphs herein by reference.

9. On December 26, 2006, United States Patent No. 7,154,961 ("the '961 Patent") was duly and legally issued by the United States Patent and Trademark Office. The '961 Patent is titled "Constellation Rearrangement for ARQ Transmit Diversity Schemes." A true and correct copy of the '961 Patent is attached hereto as Exhibit A and incorporated herein by reference.

10. Swirlate is the assignee of all right, title, and interest in the '961 patent, including all rights to enforce and prosecute actions for infringement and to collect damages for all relevant times against infringers of the '961 Patent. Accordingly, Swirlate possesses the exclusive right and standing to prosecute the present action for infringement of the '961 Patent by Defendant.

11. The invention in the '961 Patent relates to the field of Automatic Repeat reQuest ("ARQ") transmission techniques in wireless communication systems. (Ex. A at col. 1:6-8). In particular, it relates to a method for transmitting data using transmit diversity schemes in which data packets are transmitted using a first and second transmission based on a repeat request and the bit-to-symbol mapping is performed differently for different transmitted diversity branches. (*Id.* at col. 1:8-12). The inventors recognized a problem in prior art of the use of ARQ transmission techniques in wireless communication systems with unreliable and time-varying channel conditions and the invention results in an improved performance avoiding transmission errors. (*Id.* at col. 1:12-15).

12. In telecommunications, in order to improve the reliability of data transmissions, the prior art had several transmit diversity techniques in which redundant versions of identical data are transmitted in at least two diversity branches by default without explicitly requesting further diversity branches. (*Id.* at col. 1:19-24). Such transmit diversity techniques included (i) site diversity (transmitted signal originates from different sites), (ii) antenna diversity (transmitted signal originates from different antennas), (iii) polarization diversity (transmitted signal is mapped onto different polarization), (iv) frequency diversity (transmitted signal is mapped on different carrier frequencies or frequency hopping sequences), (v) time diversity (transmitted signal is mapped on different interleaving sequences), and (vi) multicode diversity (transmitted signal is mapped on different codes). (*Id.* at col. 1:24-42). The diversity branches would then be combined in order to improve the reliability of the received data. These diversity combining techniques included (a) selection combining (selecting the diversity branch with the highest Signal-to-Noise Ratio ("SNR") for decoding and ignoring the remaining ones), (b) equal gain combining (combining received diversity branches with ignoring the differences in received SNR), and (c)

maximum ratio combining (combining received diversity branches taking the received SNR of each diversity branch into account).

13. The prior art also had techniques for error detection/correction with respect to the transmission of data. For example, the prior art would use ARQ schemes together with Forward Error Correction (FEC),[1] which is called hybrid ARQ ("HARQ"). If an error is detected within a packet by the Cyclic Redundancy Check ("CRC"), the receiver requests that the transmitter send additional information (*e.g.*, retransmission) to improve the probability to correctly decode the erroneous packet. (*Id.* at col. 1: 59-63).

14. The '961 discussed a particular prior art reference that had the shortcomings of the prior art. WO-02/067491 A1 disclosed a method for HARQ transmission that averages the bit reliability over successively requested retransmissions by means of signal constellation rearrangement. (*Id.* at col. 1: 64-67). The reference showed that when more than 2 bits of data were mapped onto one modulation symbol, the bits have different reliability depending on the chosen mapping. (*Id.* at col. 2: 1-5). For most FEC schemes, this leads to a degraded decoder performance compared to an input of more equally distributed bit reliabilities. (*Id.* at col. 2:5-7). As a result, in conventional communications systems the modulation dependent variations in bit reliabilities are not considered and, therefore, usually the variations remain after combining the diversity branches at the receiver. (*Id.* at col. 2:8-11).

15. The inventors therefore developed a method that improved performance with regard to transmission errors. (*Id.* at col. 2:15-18). The idea of the invention is to improve

[1] FEC is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. The general idea of FED is that a sender encodes the message in a redundant way, most often using an error correction code. The redundancy allows the receiver to detect a limited number of errors that may occur anywhere in the message, and to potentially correct these errors without re-transmission.

performance at the receiver by applying different signal constellation mappings to the available distinguishable transmit diversity branches and ARQ retransmissions. (*Id.* at col. 2:20-23). The invention is applicable to modulation formats in which more than 2 bits are mapped onto one modulation symbol, since this implies a variation in reliabilities for the bits mapped onto the signal constellation. (*Id.* at col. 2:23-29).

16. **Direct Infringement.** Upon information and belief, Defendant has been directly infringing at least claim 1 of the '961 patent in Illinois, and elsewhere in the United States, by performing actions comprising at least performing the claimed ARQ re-transmission method by performing the steps of the claimed invention using the RAB Lightcloud Gateway 4G ("Accused Instrumentality") (*e.g.*, https://www.rablighting.com/product/LCGATEWAY/4G/VZ#technical-specification).

17. The Accused Instrumentality practices an ARQ re-transmission (*e.g.*, HARQ method) method in a wireless communication system (*e.g.*, LTE network) wherein data packets are transmitted from a transmitter (*e.g.*, the Accused Instrumentality) to a receiver (*e.g.*, LTE base station) using a first transmission (*e.g.*, HARQ transmission) and at least a second transmission (*e.g.*, HARQ retransmission) based on a repeat request (*e.g.*, HARQ retransmission request in the form of NAK).

LCGATEWAY/4G/VZ

- Connects with up to 200 Lightcloud devices
- Communicates with Lightcloud devices via 2.4 GHz wireless mesh network
- Cloud-based management - no software to install or maintain
- Connects to Lightcloud service using secure cellular 4G connection and no internet access is required
- Easy setup - simply power on, confirm a cellular signal and call 844-LIGHTCLOUD

(*E.g.*, https://www.rablighting.com/product/LCGATEWAY/4G/VZ#technical-specification).

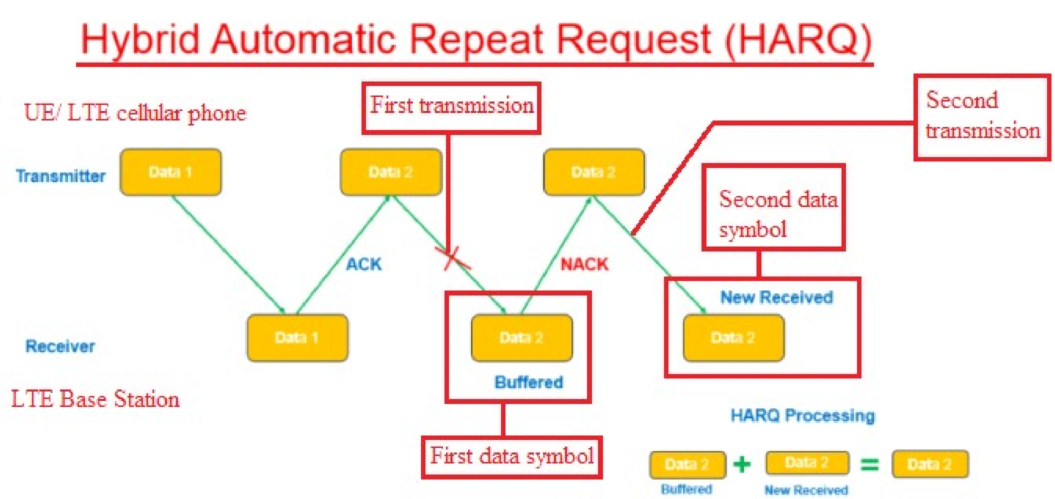
Hybrid Automatic Repeat Request (HARQ) in LTE FDD

October 18, 2018 admin Future Network Optimization, LTE, RF Basics, Tech Fundas

HARQ stands for Hybrid Automatic Repeat Request. **HARQ = ARQ + FEC** (Forward Error Correction)/Soft Combining.

ARQ refers to Automatic Repeat Request i.e. if sender doesn't receive Acknowledgement (ACK) before timeout, the receiver discards the bad packet and sender shall re-transmits the packet. ARQ procedure is illustrated below :

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

6.1 Uplink model

Data packets transmitted from a transmitter i.e. UE/ LTE cellular phone to a receiver i.e. LTE base station

6.1.1 Uplink Shared Channel

The physical-layer model for Uplink Shared Channel transmission is described based on the corresponding physical-layer-processing chain, see Figure 6.1.1. Processing steps that are relevant for the physical-layer model, e.g. in the sense that they are configurable by higher layers, are highlighted in blue. It should be noted that, in case PUSCH, the scheduling decision is partly made at the network side, if there is no blind decoding it is fully done at the network side. The uplink transmission control in the UE then configures the uplink physical-layer processing, based on uplink transport-format and resource-assignment information received on the downlink.

- **Higher-layer data passed to/from the physical layer**
- One transport block of dynamic size delivered to the physical layer once every TTI.
- **CRC and transport-block-error indication**
- Transport-block-error indication delivered to higher layers.
- **FEC and rate matching**
- Channel coding rate is implicitly given by the combination of transport block size, modulation scheme and resource assignment;

ARQ re-transmission method

- Physical layer model support of HARQ: in case of Incremental Redundancy, the corresponding Layer 2 Hybrid-ARQ process controls what redundancy version is to be used for the physical layer transmission for each TTI.
- **Interleaving**
- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

Second transmission i.e. re-transmission based on a repeat request i.e. NAK

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

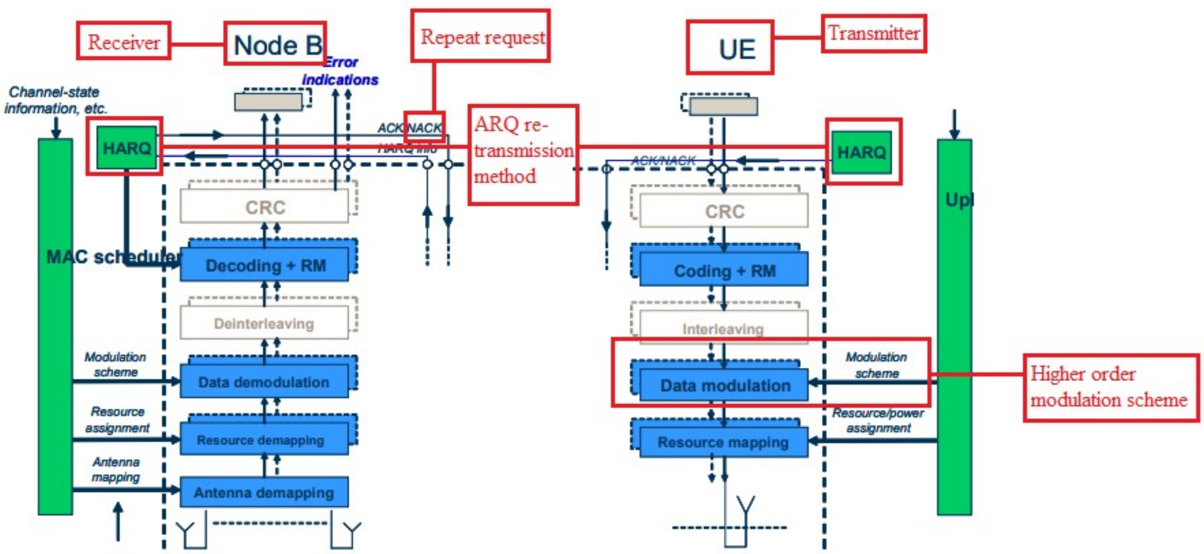


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

18. Upon information and belief, the Accused Instrumentality practices modulating data packets at the transmitter (*e.g.*, the Accused Instrumentality) using a first modulation scheme (*e.g.*, one of QPSK,16QAM and 64 QAM) to obtain first data symbols (*e.g.*, output of modulation block performing said first modulation scheme).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

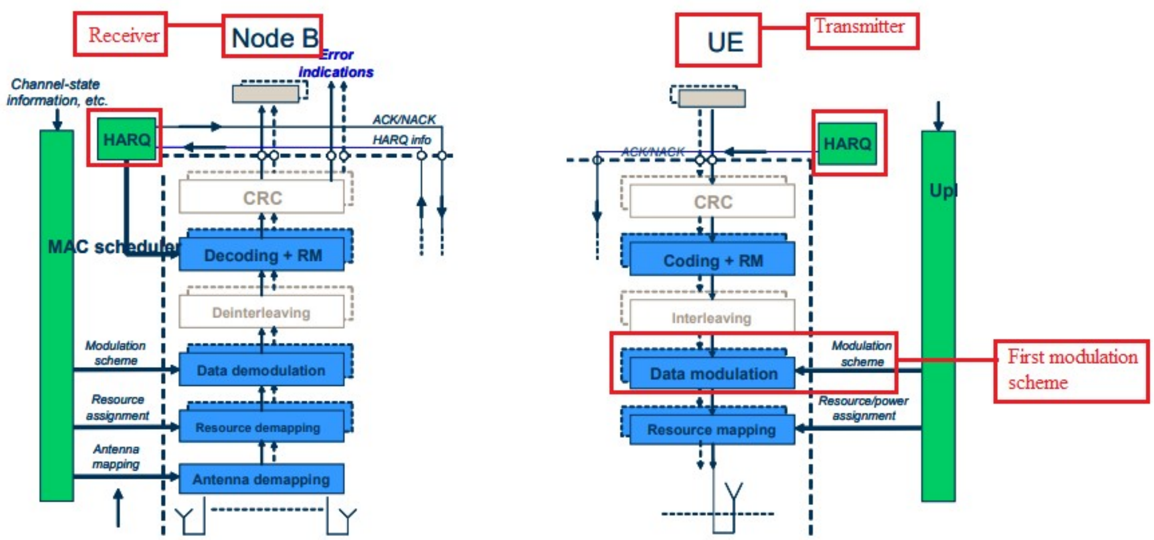


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

19. The Accused Instrumentality practices performing the first transmission (*e.g.*, HARQ transmission) by transmitting the first data symbols (*e.g.*, output of modulation block performing said first modulation scheme) over a first diversity branch to the receiver (*e.g.*, mapping from assigned resource blocks to the first available number of antenna ports). The Accused Instrumentality discloses a first diversity branch wherein the output of modulation block *i.e.,* first data symbols is transmitted over a first diversity branch which is indicated in case of

Multi-antenna processing wherein mapping from assigned resource blocks to the first available number of antenna ports.

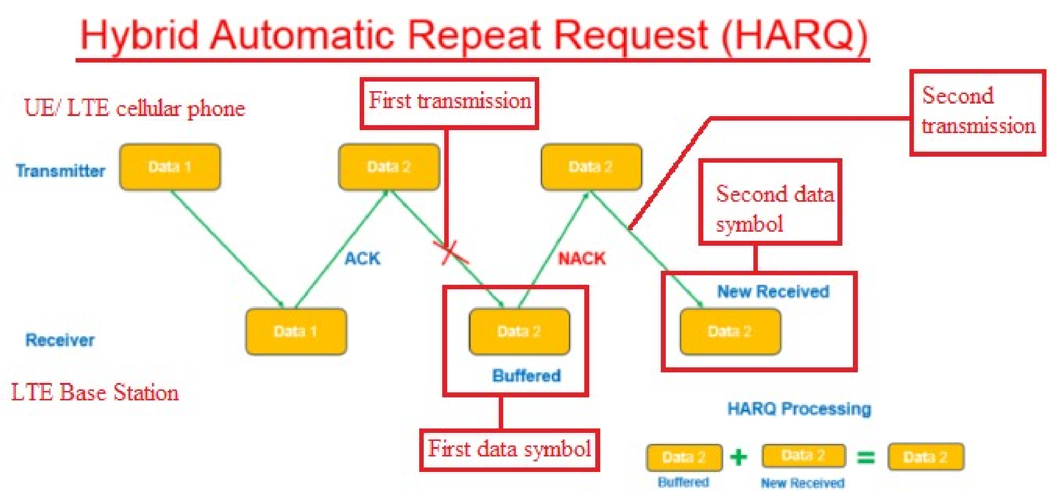
Hybrid Automatic Repeat Request (HARQ) in LTE FDD

October 18, 2018 admin Future Network Optimization, LTE, RF Basics, Tech Fundas

HARQ stands for Hybrid Automatic Repeat Request. **HARQ = ARQ + FEC** (Forward Error Correction)/Soft Combining.

ARQ refers to Automatic Repeat Request i.e. if sender doesn't receive Acknowledgement (ACK) before timeout, the receiver discards the bad packet and sender shall re-transmits the packet. ARQ procedure is illustrated below :

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



(*E.g.*,http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment. Transmitting the first data symbols over a first diversity branch to the receiver
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

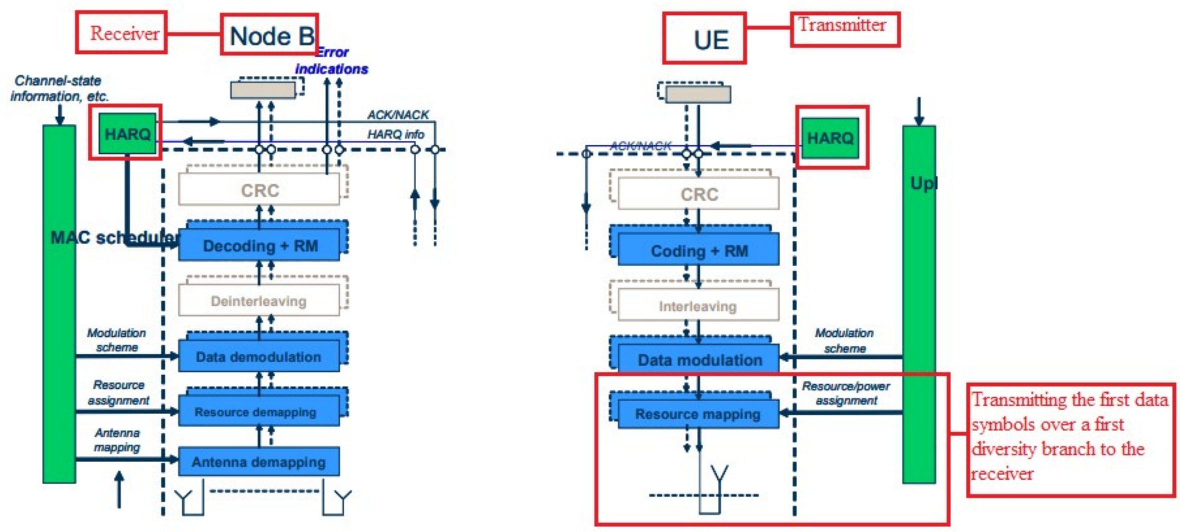


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

specific reference signals within the considered measurement frequency bandwidth. For RSRP determination the cell-specific reference signals R_0 and if available R_1 according to [8] can be used.

If receiver diversity is in use by the UE, the reported value shall be equivalent to the linear average of the power values of all diversity branches.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

5.2 Overview of L1 functions

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

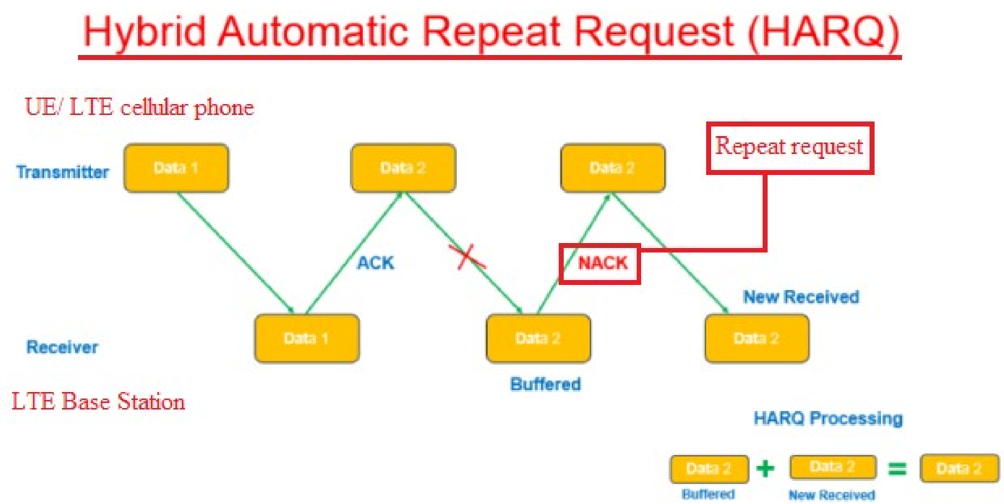
- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Beamforming
- RF processing. (Note: RF processing aspects are specified in the TS 36.100)

L1 functions are modelled for each transport channel in subclauses 6.1 and 6.2.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

20. Upon information and belief, the Accused Instrumentality practices modulating said data packets at the transmitter (*e.g.*, the Accused Instrumentality) using a second modulation scheme (*e.g.*, one of QPSK, 16QAM and 64 QAM)—which is distinct from the first modulation scheme) to obtain second data symbols (*e.g.*, output of modulation block using a second modulation scheme). As shown below, the Accused Instrumentality on repeat request *i.e.,* receiving the retransmission request in the form of NAK, enables a second mapping of said higher order modulation scheme (*i.e.,* an Adaptive Re-transmission having a different Modulation Coding Scheme (MCS) than the one used for HARQ transmission *i.e.,* first higher order modulation scheme).

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



HARQ Re-transmissions Types

HARQ Re-transmissions are also of 2 types:-

- Adaptive re-transmission,
- Non-adaptive re-transmission.

Adaptive Re-transmission: Second mapping of said higher order modulation scheme for re-transmission

Here, the transmission attributes like Modulation Coding Scheme **(MCS)**, Redundancy Version **(RV)**, **sub-carrier** on which transmission is going to occur, does not remain same during each re-transmission but are notified by the sender. These attributes can be changed according to radio channel conditions, hence, it again provides flexibility but increases overhead.

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).

Higher order modulation scheme

- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

Second transmission i.e. re-transmission based on a repeat request i.e. NAK

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

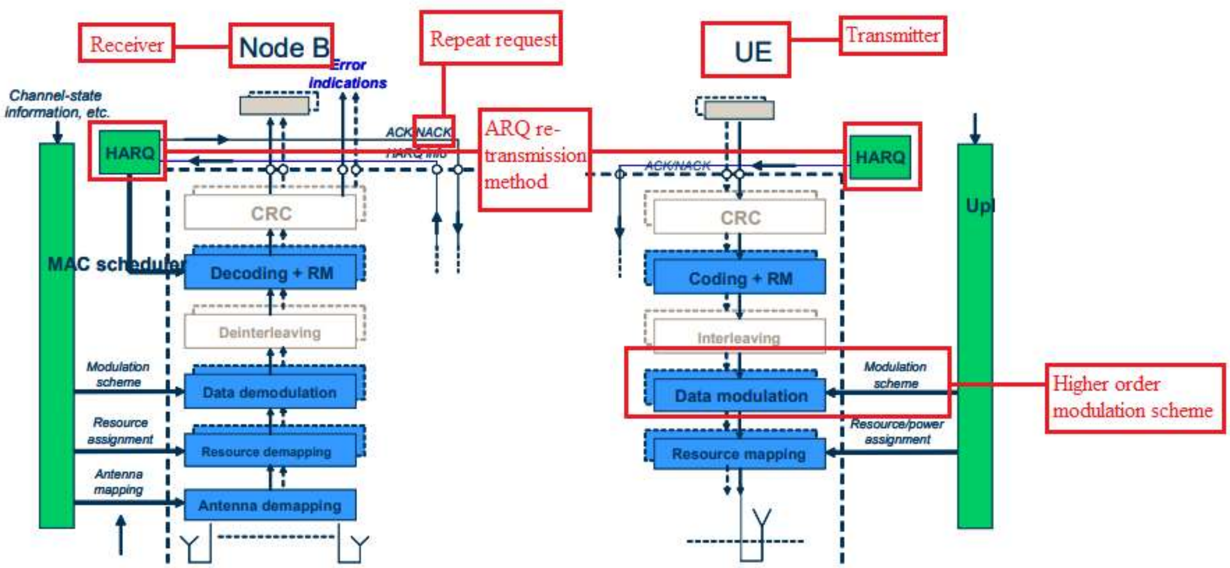


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

QAM bits per symbol

Higher order modulation scheme

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

QAM FORMATS & BIT RATES COMPARISON

MODULATION	BITS PER SYMBOL	SYMBOL RATE
BPSK	1	1 x bit rate
QPSK	2	1/2 bit rate
8PSK	3	1/3 bit rate
16QAM	4	1/4 bit rate
32QAM	5	1/5 bit rate
64QAM	6	1/6 bit rate

Respresenting more than two data bits are mapped onto one data symbol

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

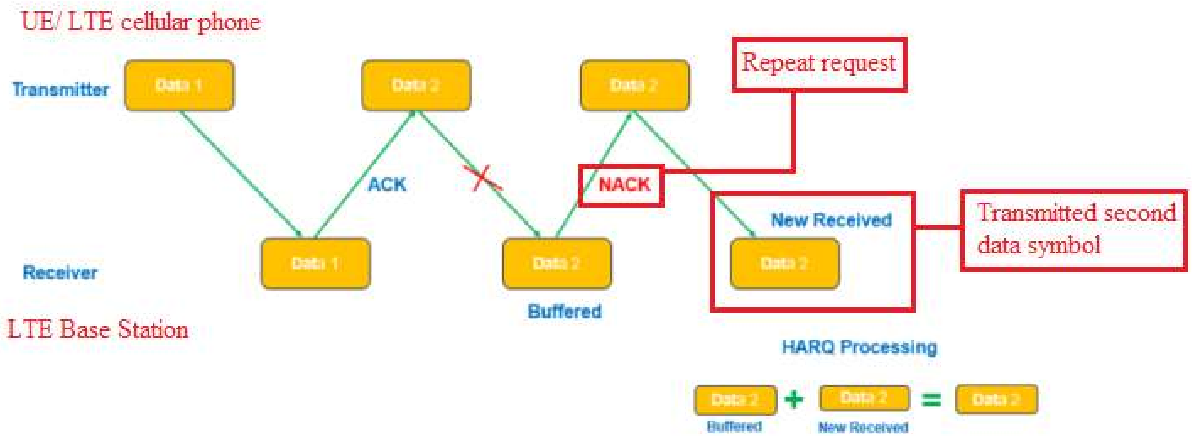
(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

21. Upon information and belief, the Accused Instrumentality practices performing the second transmission (*e.g.*, HARQ retransmission) by transmitting the second data symbols (*e.g.*, output of modulation block using a second modulation scheme) over a second diversity branch (*e.g.*, mapping from assigned resource blocks to the later available number of antenna ports) to the receiver (*e.g.*, LTE base station). The Accused Instrumentality discloses a second diversity branch wherein the output of modulation block *i.e.*, second data symbols is transmitted over a second or

later diversity branch which is indicated in case of Multi-antenna processing wherein mapping from assigned resource blocks to the later available number of antenna ports.

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows

Hybrid Automatic Repeat Request (HARQ)



HARQ Re-transmissions Types

HARQ Re-transmissions are also of 2 types:-

- Adaptive re-transmission,
- Non-adaptive re-transmission.

Adaptive Re-transmission:

Second mapping of said higher order modulation scheme for re-transmission

Here, the transmission attributes like Modulation Coding Scheme **(MCS)**, Redundancy Version **(RV)**, **sub-carrier** on which transmission is going to occur, does not remain same during each re-transmission but are notified by the sender. These attributes can be changed according to radio channel conditions, hence, it again provides flexibility but increases overhead.

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment.

Transmitting the second data symbols over a second diversity branch

- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

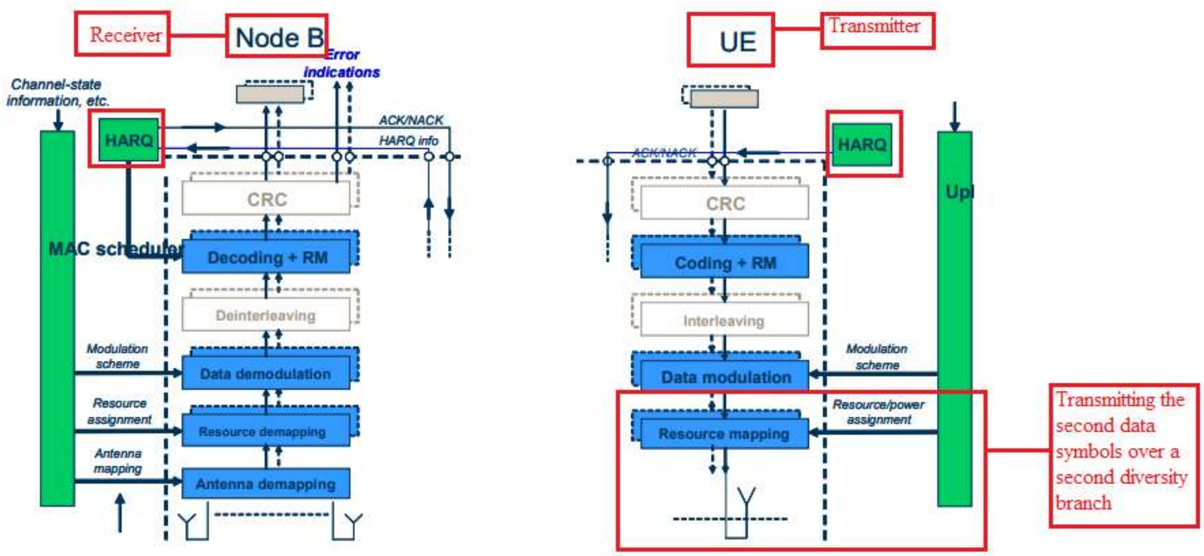


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

specific reference signals within the considered measurement frequency bandwidth. For RSRP determination the cell-specific reference signals R_0 and if available R_1 according to [8] can be used.

If receiver diversity is in use by the UE, the reported value shall be equivalent to the linear average of the power values of all diversity branches.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

5.2 Overview of L1 functions

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Beamforming
- RF processing. (Note: RF processing aspects are specified in the TS 36.100)

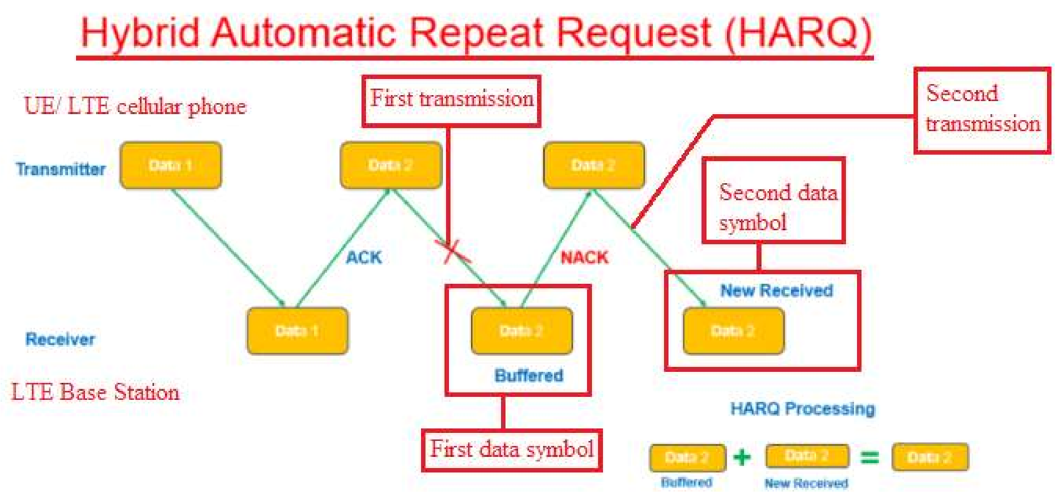
L1 functions are modelled for each transport channel in subclauses 6.1 and 6.2.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

22. Upon information and belief, the Accused Instrumentality, at least in its internal testing and usage, utilizes a base station which practices demodulating the received first (*e.g.*, output of modulation block performing said first modulation scheme) and second data symbols (*e.g.*, output of modulation block using a second modulation scheme) at the receiver (*e.g.*, LTE Base Station) using the first and second modulation schemes (*e.g.*, the mappings corresponding to transmission and retransmission Modulation Coding Scheme) respectively. As shown below, the

Accused Instrumentality, at least in its internal testing and usage, utilizes a base station which practices demodulation of first (*e.g.*, output of modulation block performing said first modulation scheme) and second data symbols (*e.g.*, output of modulation block using a second modulation scheme) at the LTE Base Station using the first and second modulation scheme *i.e.,* Modulation Coding Scheme which are distinct for transmission and Adaptive Re-transmission (*i.e.,* an Adaptive Re-transmission having a different Modulation Coding Scheme (MCS) than the one used for transmission *i.e.* first higher order modulation scheme).

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



HARQ Re-transmissions Types

HARQ Re-transmissions are also of 2 types:-

- Adaptive re-transmission,
- Non-adaptive re-transmission.

Adaptive Re-transmission: Second mapping of said higher order modulation scheme for re-transmission

Here, the transmission attributes like Modulation Coding Scheme **(MCS)**, Redundancy Version **(RV)**, **sub-carrier** on which transmission is going to occur, does not remain same during each re-transmission but are notified by the sender. These attributes can be changed according to radio channel conditions, hence, it again provides flexibility but increases overhead.

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).

Higher order modulation scheme

- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

Second transmission i.e. re-transmission based on a repeat request i.e. NAK

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

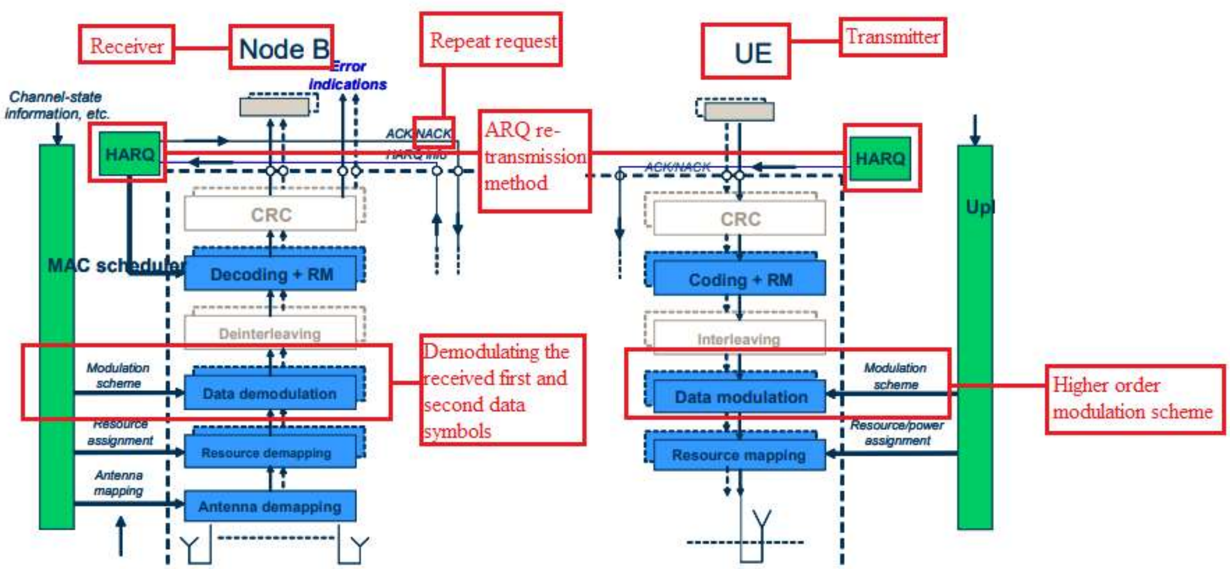


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*,https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

QAM bits per symbol

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

QAM FORMATS & BIT RATES COMPARISON

MODULATION	BITS PER SYMBOL	SYMBOL RATE
BPSK	1	1 x bit rate
QPSK	2	1/2 bit rate
8PSK	3	1/3 bit rate
16QAM	4	1/4 bit rate
32QAM	5	1/5 bit rate
64QAM	6	1/6 bit rate

Respresenting more than two data bits are mapped onto one data symbol

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

23. Upon information and belief, The Accused Instrumentality, at least in its internal testing and usage, utilizes a base station which practices diversity combining (*e.g.*, Hybrid ARQ soft-combining) the demodulated data received over the first (*e.g.*, mapping from assigned resource blocks to the first available number of antenna ports) and second diversity branches (*e.g.*, mapping from assigned resource blocks to the later available number of antenna ports). The Accused Instrumentality, at least in its internal testing and usage, utilizes a base station which

performs a diversity combining *i.e.*, Hybrid ARQ soft-combining of data from multiple received antenna ports.

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

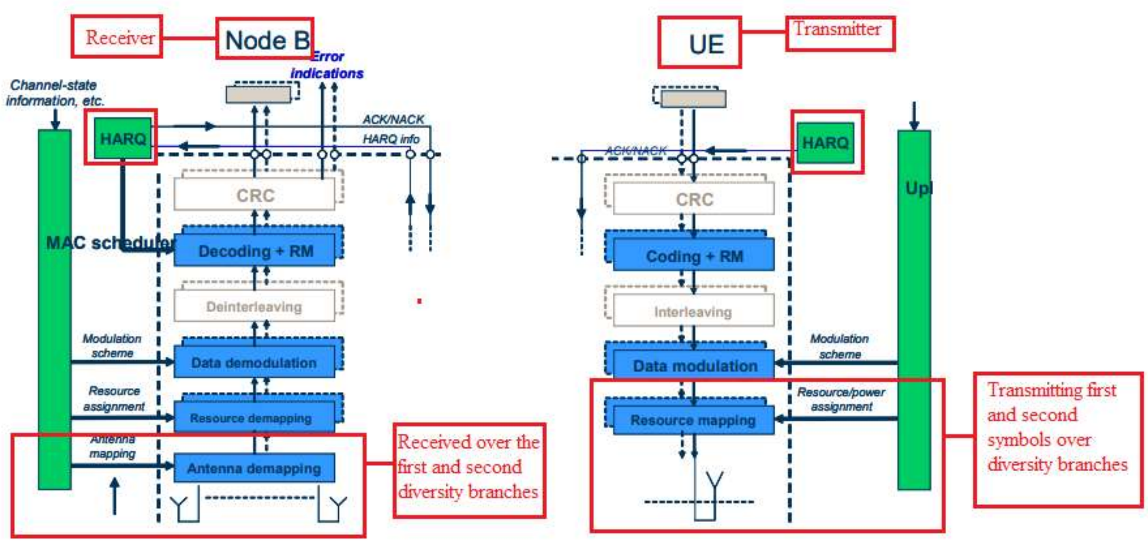


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

specific reference signals within the considered measurement frequency bandwidth. For RSRP determination the cell-specific reference signals R_0 and if available R_1 according to [8] can be used.

If receiver diversity is in use by the UE, the reported value shall be equivalent to the linear average of the power values of all diversity branches.

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

5.2 Overview of L1 functions

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

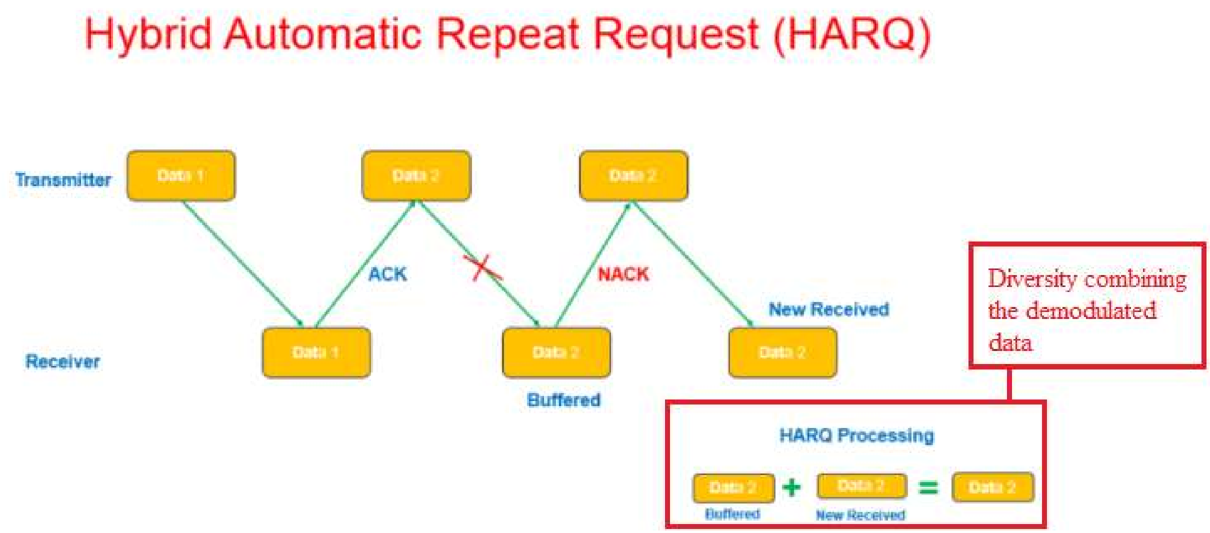
- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining Diversity combining
- Rate matching of the coded transport channel to physical channels

- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Beamforming
- RF processing. (Note: RF processing aspects are specified in the TS 36.100)

L1 functions are modelled for each transport channel in subclauses 6.1 and 6.2.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

24. Upon information and belief, the Accused Instrumentality utilizes the modulation schemes wherein 16 QAM and a number of log2 (M) modulation schemes are used. The Accused Instrumentality performs a data modulation such as QPSK, 16 QAM and 64 QAM wherein the M-ary Quadrature Amplitude Modulation is basically a log2 (M) modulation schemes, for example,16QAM stands for log2 (16) modulation schemes and 64 QAM stands for log2 (64) modulation schemes.

Hybrid Automatic Repeat Request (HARQ) in LTE FDD

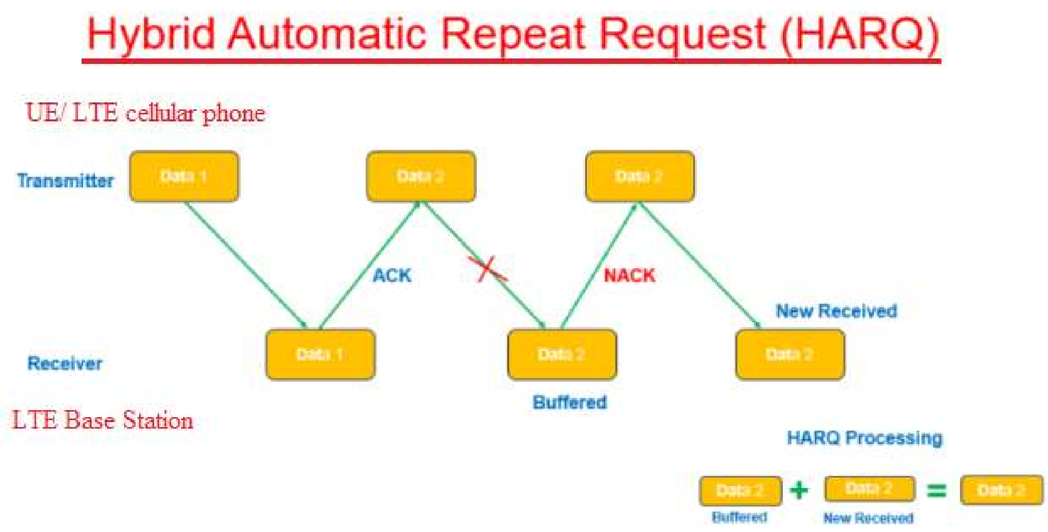
October 18, 2018 admin Future Network Optimization, LTE, RF Basics, Tech Fundas

HARQ stands for Hybrid Automatic Repeat Request. **HARQ = ARQ + FEC** (Forward Error Correction)/Soft Combining.

ARQ refers to Automatic Repeat Request i.e. if sender doesn't receive Acknowledgement (ACK) before timeout, the receiver discards the bad packet and sender shall re-transmits the packet. ARQ procedure is illustrated below :

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource** 16 QAM and a number of log2 (M) modulation schemes
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

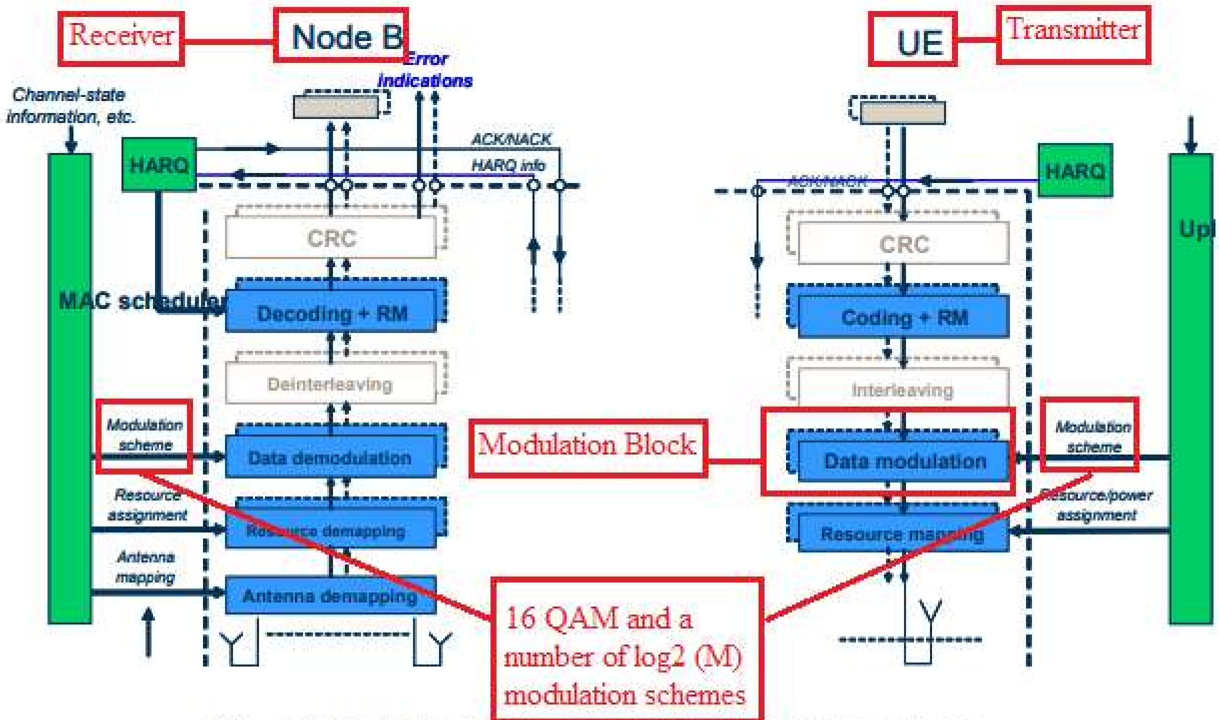


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

Constructing a rectangular constellation for 16-QAM

October 10, 2012 by Mathuranathan

★★★★★ (7 votes, average: 4.57 out of 5)
This post is a part of the ebook : Digital Modulations using Matlab: build simulation models from scratch – by Mathuranathan Viswanathan

Any rectangular QAM constellation is equivalent to superimposing two ASK signals on quadrature carriers (I and Q components). For 4-QAM modulation, each symbol is of size k = log2(M) = log2(4) = 2 bits. For 16-QAM modulation, the symbol size is k = log2(16) = 4 bits.

(*E.g.*, https://www.gaussianwaves.com/2012/10/constructing-a-rectangular-constellation-for-16-qam/).

QAM bits per symbol

Higher order modulation scheme

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

IV. COUNT II
(PATENT INFRINGEMENT OF UNITED STATES PATENT NO. 7,567,622)

25. Plaintiff incorporates the above paragraphs herein by reference.

26. On July 28, 2009, United States Patent No. 7,567,622 ("the '622 Patent") was duly and legally issued by the United States Patent and Trademark Office. The '622 Patent is titled "Constellation Rearrangement for ARQ Transmit Diversity Schemes." The '622 patent issued from an application that is a continuation of the application leading to the '961 patent. A true and

correct copy of the ‘622 Patent is attached hereto as Exhibit B and incorporated herein by reference.

27. Swirlate is the assignee of all right, title, and interest in the ‘622 patent, including all rights to enforce and prosecute actions for infringement and to collect damages for all relevant times against infringers of the ‘622 Patent. Accordingly, Swirlate possesses the exclusive right and standing to prosecute the present action for infringement of the ‘622 Patent by Defendant.

28. The ‘622 patent shares the same specification as the ‘961 patent and therefore the background information regarding the ‘961 patent in paragraphs 11 through 15 are incorporated by reference.

29. During the prosecution history, applicant explained the benefits of the claimed invention. The claim “defines an ARQ retransmission method in which more than two data bits are mapped onto one data symbol in each of the initial transmission and a retransmission. The symbols of the initial transmission and the retransmission represent the same bit information, but are different symbols due to different bit mappings. Since different bits of a modulation symbol have different communications reliabilities, the claimed subject matter supports averaging the communication reliabilities for each bit mapped onto a transmission symbol and a retransmission symbol so as to improve the likelihood of receiving the bit.” (Ex. C at 16).

30. An advantage of the claimed subject matter “lies in reducing the overall data traffic, since the claimed retransmission is only needed in situations where any initial transmission cannot be successfully received by a receiver. The claimed subject matter employs retransmission and diversity combining only when the initial transmission is not received properly, whereas [the prior art] communications scheme always transmits identical data over three parallel paths for diversity

combining by a receiver and does not retransmit data in accordance with a repeat request by a receiver." (Ex. C at 17).

31. **Direct Infringement.** Upon information and belief, Defendant has been directly infringing at least claim 1 of the '622 patent in Illinois, and elsewhere in the United States, by performing actions comprising at least performing the claimed ARQ re-transmission method by performing the steps of the claimed invention using RAB Lightcloud Gateway 4G ("Accused Instrumentality") (*e.g.*, https://www.rablighting.com/product/LCGATEWAY/4G/VZ#technical-specification).

32. The Accused Instrumentality practices an ARQ re-transmission method (*e.g.*, HARQ method) in a wireless communication system (*e.g.*, LTE network) wherein data packets are transmitted from a transmitter (*e.g.*, the Accused Instrumentality) to a receiver (*e.g.*, LTE base station) using a higher order modulation scheme (*e.g.*, one of QPSK,16QAM and 64 QAM) wherein more than two data bits are mapped onto one data symbol to perform a first transmission and at least a second transmission (*e.g.*, HARQ retransmission) based on a repeat request (*e.g.*, HARQ retransmission request in the form of NAK). The Accused Instrumentality performs a higher order data modulation such as 16QAM and 64 QAM wherein has more than two data bits are mapped onto one data symbol (*i.e.,* in case of 16QAM it transmits 4 bits per symbol whereas in the case of 64QAM it transmits 6 bits per symbol).

LCGATEWAY/4G/VZ

- Connects with up to 200 Lightcloud devices
- Communicates with Lightcloud devices via 2.4 GHz wireless mesh network
- Cloud-based management - no software to install or maintain
- Connects to Lightcloud service using secure cellular 4G connection and no internet access is required
- Easy setup - simply power on, confirm a cellular signal and call 844-LIGHTCLOUD

(*E.g.*, https://www.rablighting.com/product/LCGATEWAY/4G/VZ#technical-specification).

Hybrid Automatic Repeat Request (HARQ) in LTE FDD

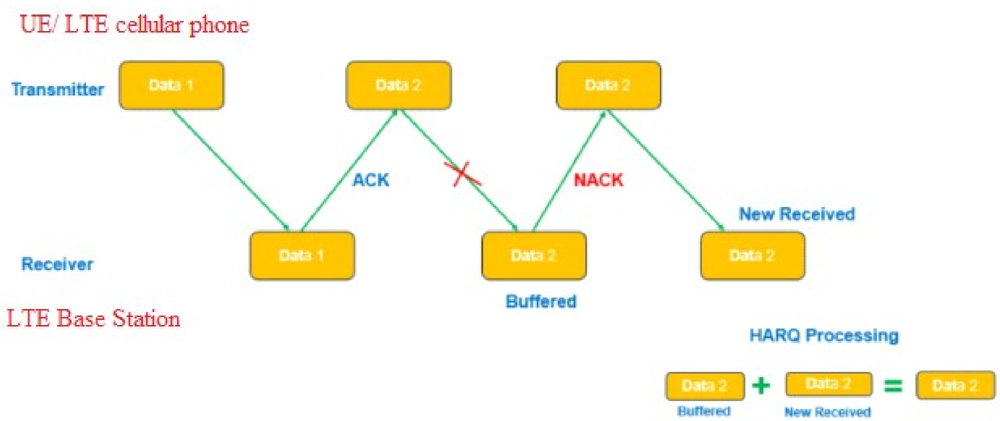
October 18, 2018 admin Future Network Optimization, LTE, RF Basics, Tech Fundas

HARQ stands for Hybrid Automatic Repeat Request. **HARQ** = **ARQ** + **FEC** (Forward Error Correction)/Soft Combining.

ARQ refers to Automatic Repeat Request i.e. if sender doesn't receive Acknowledgement (ACK) before timeout, the receiver discards the bad packet and sender shall re-transmits the packet. ARQ procedure is illustrated below :

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows

Hybrid Automatic Repeat Request (HARQ)



(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

6.1 Uplink model

Data packets transmitted from a transmitter i.e. UE/ LTE cellular phone to a receiver i.e. LTE base station

6.1.1 Uplink Shared Channel

The physical-layer model for Uplink Shared Channel transmission is described based on the corresponding physical-layer-processing chain, see Figure 6.1.1. Processing steps that are relevant for the physical-layer model, e.g. in the sense that they are configurable by higher layers, are highlighted in blue. It should be noted that, in case PUSCH, the scheduling decision is partly made at the network side, if there is no blind decoding it is fully done at the network side. The uplink transmission control in the UE then configures the uplink physical-layer processing, based on uplink transport-format and resource-assignment information received on the downlink.

- **Higher-layer data passed to/from the physical layer**
- One transport block of dynamic size delivered to the physical layer once every TTI.
- **CRC and transport-block-error indication**
- Transport-block-error indication delivered to higher layers.
- **FEC and rate matching**
- Channel coding rate is implicitly given by the combination of transport block size, modulation scheme and resource assignment;

ARQ re-transmission method

- Physical layer model support of HARQ: in case of Incremental Redundancy, the corresponding Layer 2 Hybrid-ARQ process controls what redundancy version is to be used for the physical layer transmission for each TTI.
- **Interleaving**
- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).

Higher order modulation scheme

- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

Second transmission i.e. re-transmission based on a repeat request i.e. NAK

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

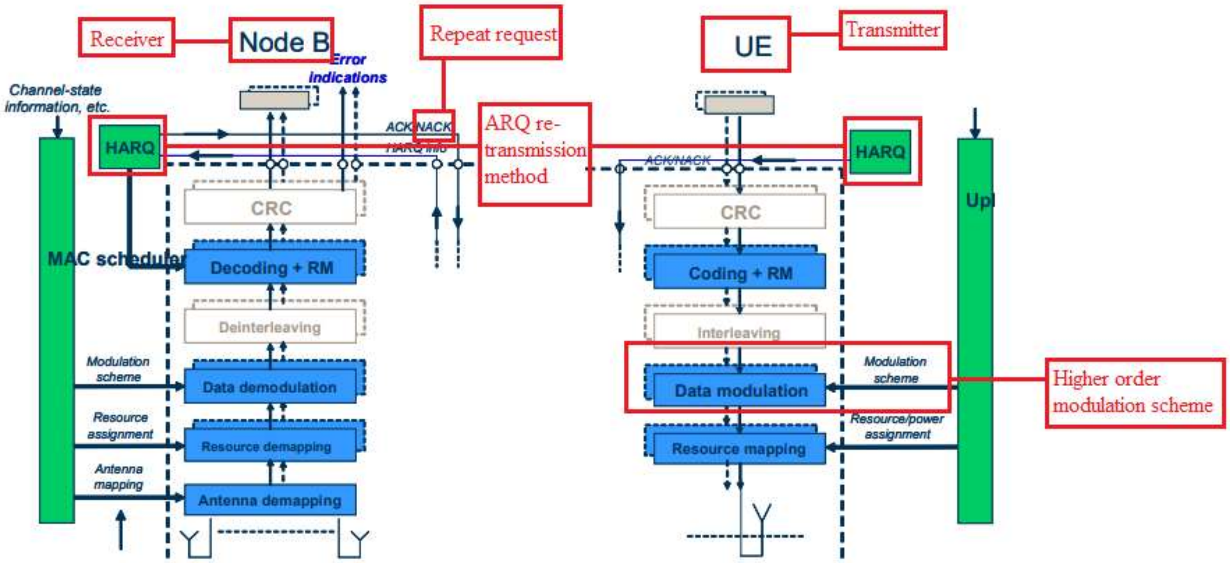


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

QAM bits per symbol

Higher order modulation scheme

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

QAM FORMATS & BIT RATES COMPARISON

MODULATION	BITS PER SYMBOL	SYMBOL RATE
BPSK	1	1 x bit rate
QPSK	2	1/2 bit rate
8PSK	3	1/3 bit rate
16QAM	4	1/4 bit rate
32QAM	5	1/5 bit rate
64QAM	6	1/6 bit rate

Respresenting more than two data bits are mapped onto one data symbol

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
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(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

33. Upon information and belief, the Accused Instrumentality practices modulating data packets at the transmitter (*e.g.*, the Accused Instrumentality) using a first mapping of said higher order modulation scheme (*e.g.*, one of QPSK, 16QAM and 64 QAM) to obtain first data symbols (*e.g.*, output of modulation block performing said first modulation scheme). The Accused Instrumentality performs a higher order data modulation such as 16QAM and 64 QAM which have more than two data bits are mapped onto one data symbol (*i.e.,* in case of 16QAM it transmits 4

bits per symbol whereas in the case of 64QAM it transmits 6 bits per symbol) so as to obtain a said first data symbols which is basically the output of the modulation block.

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment.

Higher order modulation scheme

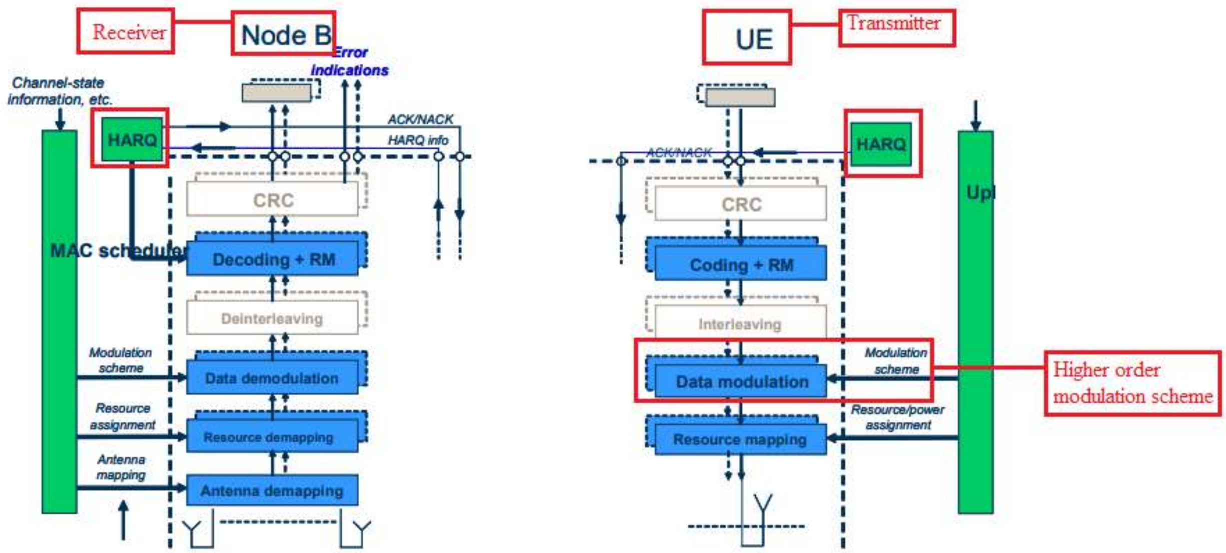

Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

QAM bits per symbol

Higher order modulation scheme

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

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(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

34. Upon information and belief, the Accused Instrumentality practices performing the first transmission by transmitting the first data symbols (*e.g.*, output of modulation block performing said first modulation scheme) over a first diversity branch to the receiver (*e.g.*, mapping from assigned resource blocks to the first available number of antenna ports). The

Accused Instrumentality discloses a first diversity branch wherein the output of modulation block, *i.e.*, first data symbols, is transmitted over a first diversity branch which is indicated in case of Multi-antenna processing wherein mapping from assigned resource blocks to the first available number of antenna ports.

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment. Transmitting the first data symbols over a first diversity branch to the receiver
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

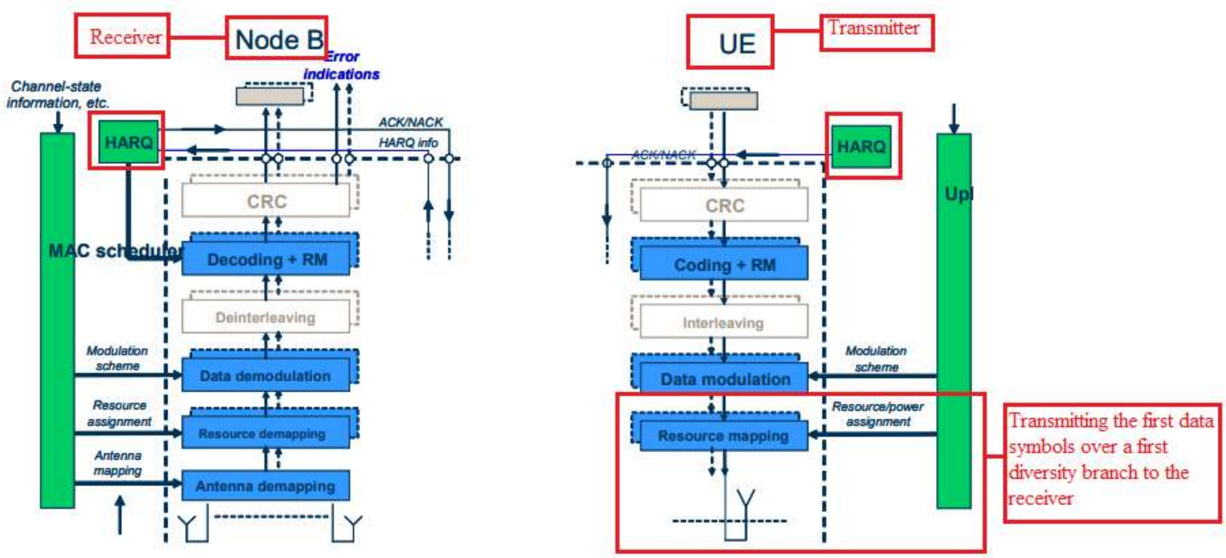
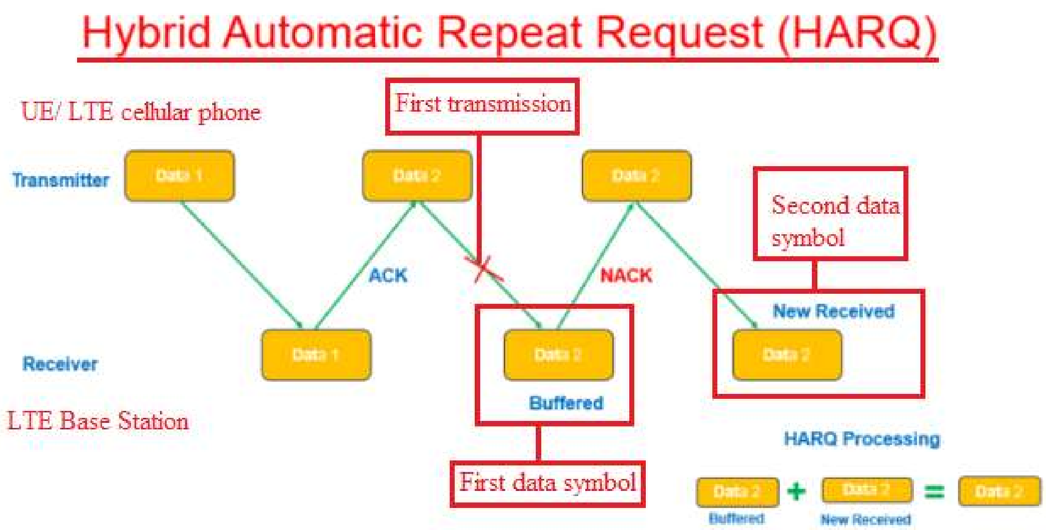


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

specific reference signals within the considered measurement frequency bandwidth. For RSRP determination the cell-specific reference signals R_0 and if available R_1 according to [8] can be used.

If receiver diversity is in use by the UE, the reported value shall be equivalent to the linear average of the power values of all diversity branches.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

5.2 Overview of L1 functions

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Beamforming
- RF processing. (Note: RF processing aspects are specified in the TS 36.100)

L1 functions are modelled for each transport channel in subclauses 6.1 and 6.2.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

35. Upon information and belief, the Accused Instrumentality practices performing receiving at the transmitter (*e.g.*, the Accused Instrumentality) the repeat request (*e.g.*, HARQ retransmission request in the form of NAK) issued by the receiver (*e.g.*, LTE base station) to retransmit the data packets in case the data packets of the first transmission have not been successfully decoded (*e.g.*, Error indication in the data received).

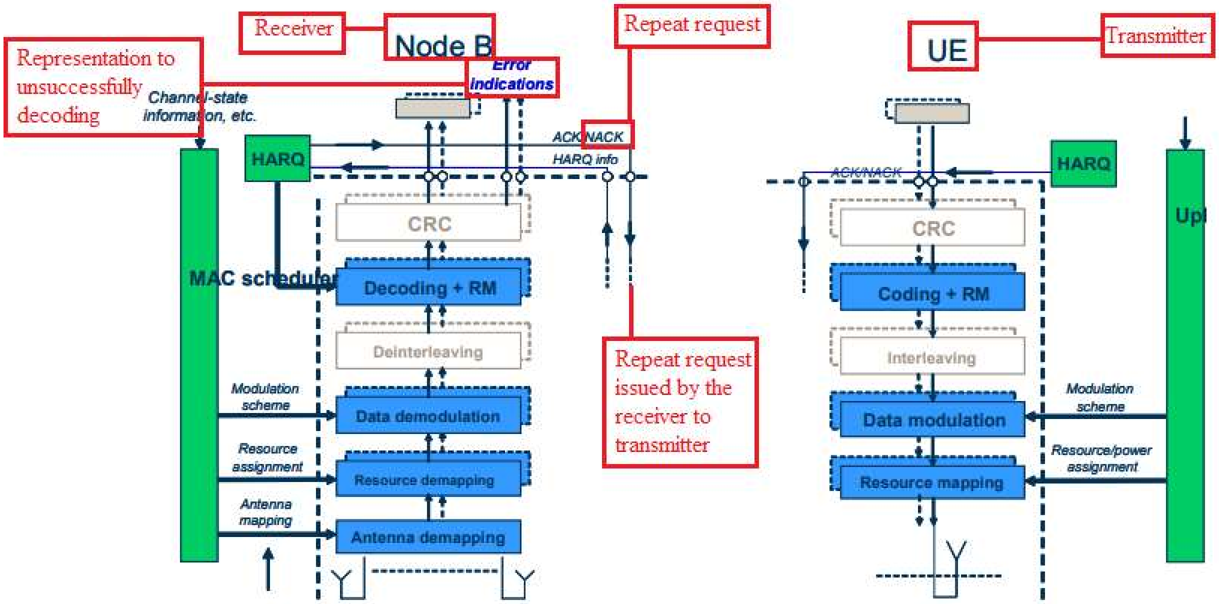


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

Hybrid Automatic Repeat Request (HARQ) in LTE FDD

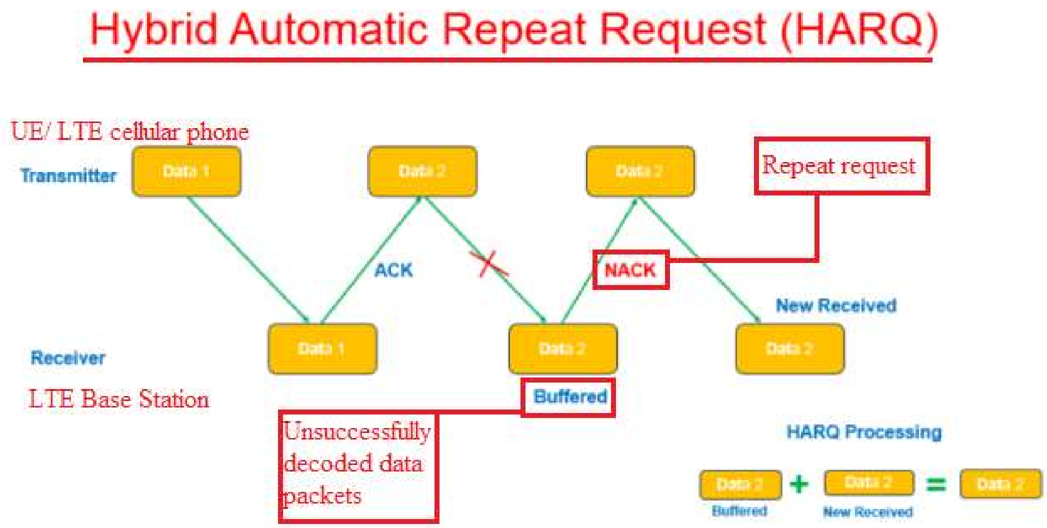
October 18, 2018 admin Future Network Optimization, LTE, RF Basics, Tech Fundas

HARQ stands for Hybrid Automatic Repeat Request. **HARQ** = **ARQ** + **FEC** (Forward Error Correction)/Soft Combining.

ARQ refers to Automatic Repeat Request i.e. if sender doesn't receive Acknowledgement (ACK) before timeout, the receiver discards the bad packet and sender shall re-transmits the packet. ARQ procedure is illustrated below :

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

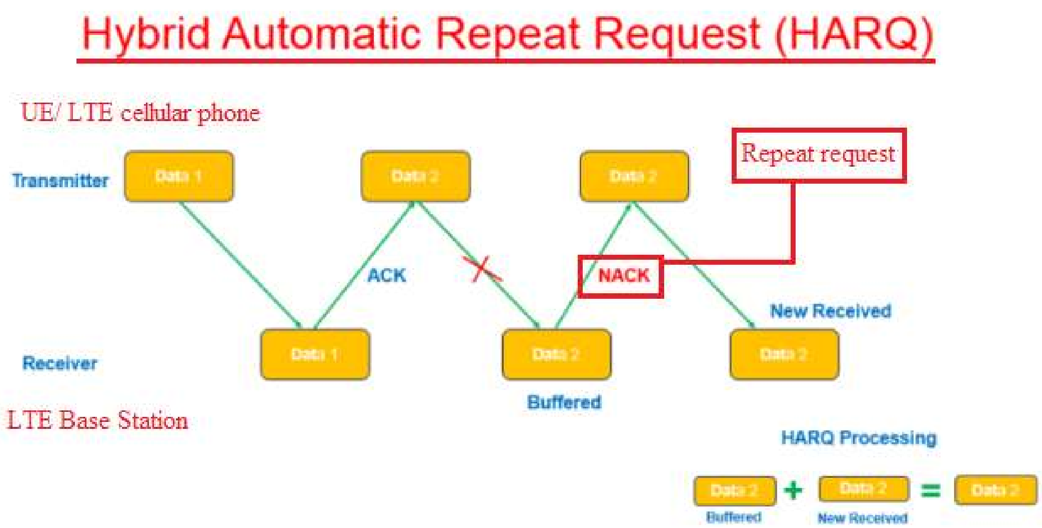
Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

36. Upon information and belief, the Accused Instrumentality practices modulating, in response to the received repeat request (*e.g.*, HARQ retransmission request in the form of NAK), said data packets at the transmitter using a second mapping of said higher order modulation scheme (*e.g.*, one of QPSK, 16QAM and 64 QAM- which is distinct from the first modulation scheme) to obtain second data symbols (*e.g.*, output of modulation block using a second modulation scheme). As shown below, the Accused Instrumentality on repeat request *i.e.,* receiving the retransmission request in the form of NAK, enables a second mapping of said higher order modulation scheme (*i.e.* an Adaptive Re-transmission having a different Modulation Coding Scheme (MCS) than the one used for transmission *i.e.* first higher order modulation scheme).

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



HARQ Re-transmissions Types

HARQ Re-transmissions are also of 2 types:-

- Adaptive re-transmission,
- Non-adaptive re-transmission.

Adaptive Re-transmission: Second mapping of said higher order modulation scheme for re-transmission

Here, the transmission attributes like Modulation Coding Scheme **(MCS)**, Redundancy Version **(RV)**, **sub-carrier** on which transmission is going to occur, does not remain same during each re-transmission but are notified by the sender. These attributes can be changed according to radio channel conditions, hence, it again provides flexibility but increases overhead.

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).

Higher order modulation scheme

- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

Second transmission i.e. re-transmission based on a repeat request i.e. NAK

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

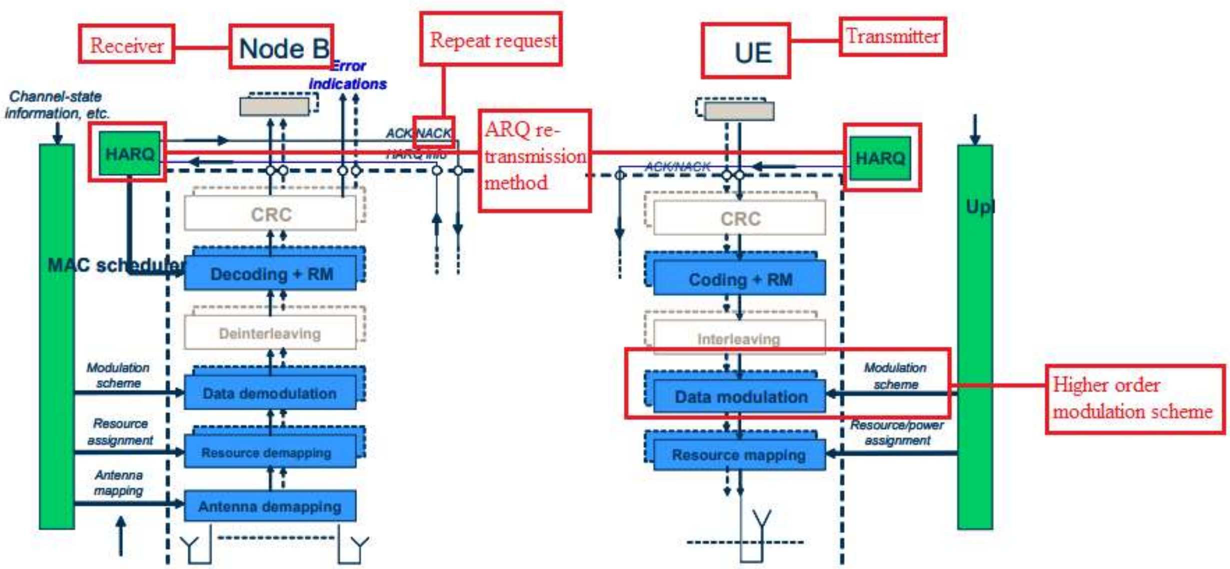


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

QAM bits per symbol

Higher order modulation scheme

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

QAM FORMATS & BIT RATES COMPARISON

MODULATION	BITS PER SYMBOL	SYMBOL RATE
BPSK	1	1 x bit rate
QPSK	2	1/2 bit rate
8PSK	3	1/3 bit rate
16QAM	4	1/4 bit rate
32QAM	5	1/5 bit rate
64QAM	6	1/6 bit rate

Respresenting more than two data bits are mapped onto one data symbol

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x = I + jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

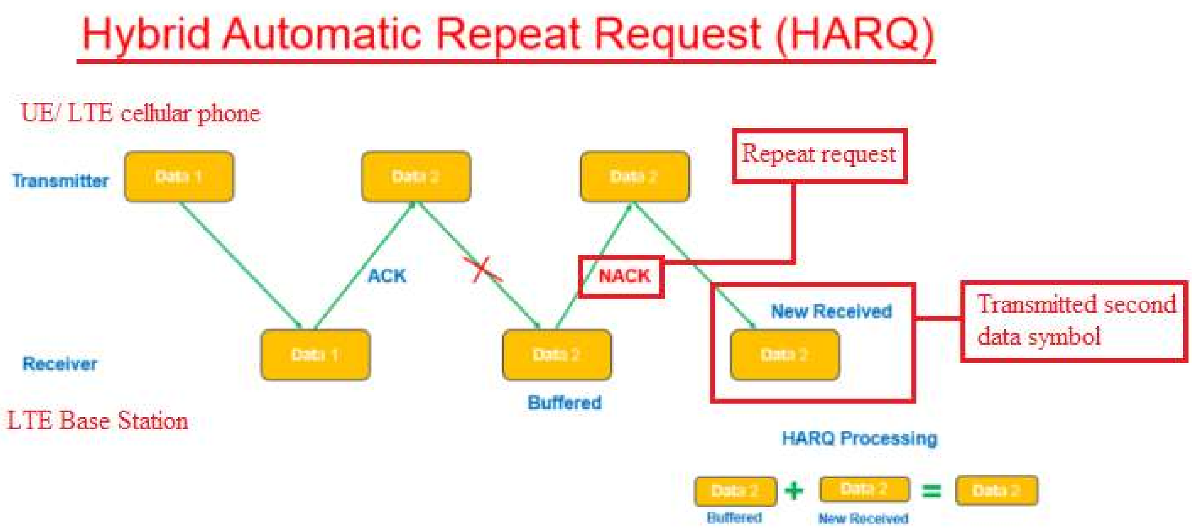
$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

37. Upon information and belief, the Accused Instrumentality practices performing, in response to the received repeat request (*e.g.*, retransmission request in the form of NAK), the second transmission (*e.g.*, retransmission) by transmitting the second data symbols (*e.g.*, output of modulation block using a second modulation scheme) over a second diversity branch to the receiver (*e.g.*, mapping from assigned resource blocks to the later available number of antenna ports). The Accused Instrumentality discloses a second diversity branch wherein the output of

modulation block *i.e.,* second data symbols is transmitted over a second or later diversity branch which is indicated in case of Multi-antenna processing wherein mapping from assigned resource blocks to the later available number of antenna ports.

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



HARQ Re-transmissions Types

HARQ Re-transmissions are also of 2 types:-

- Adaptive re-transmission,
- Non-adaptive re-transmission.

Adaptive Re-transmission: Second mapping of said higher order modulation scheme for re-transmission

Here, the transmission attributes like Modulation Coding Scheme **(MCS)**, Redundancy Version **(RV)**, **sub-carrier** on which transmission is going to occur, does not remain same during each re-transmission but are notified by the sender. These attributes can be changed according to radio channel conditions, hence, it again provides flexibility but increases overhead.

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment. Transmitting the second data symbols over a second diversity branch
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

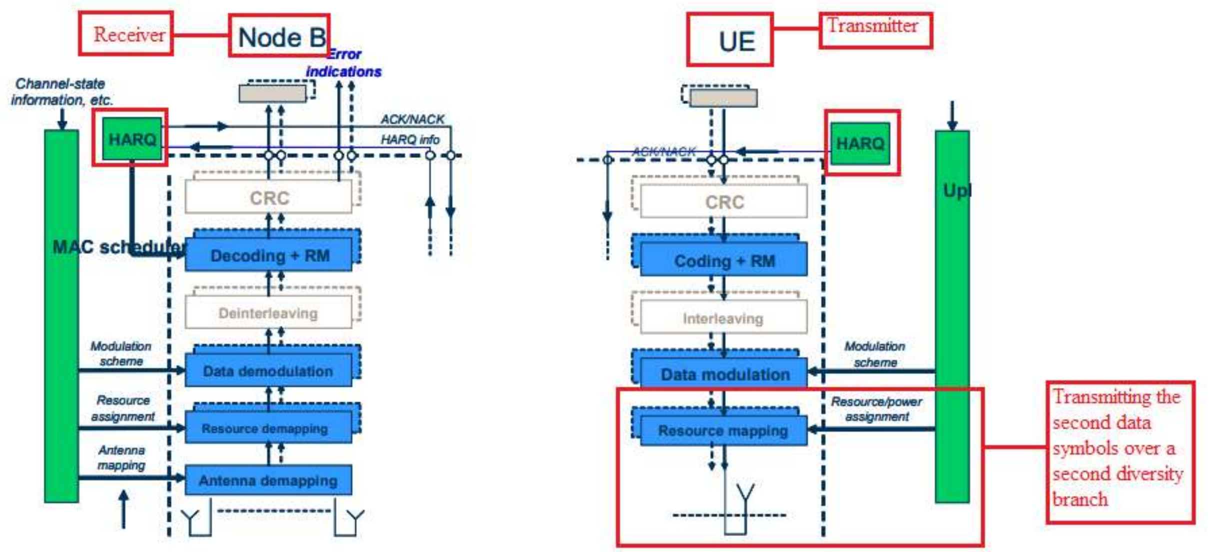


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

specific reference signals within the considered measurement frequency bandwidth. For RSRP determination the cell-specific reference signals R_0 and if available R_1 according to [8] can be used.

If receiver diversity is in use by the UE, the reported value shall be equivalent to the linear average of the power values of all diversity branches.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

5.2 Overview of L1 functions

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Beamforming
- RF processing. (Note: RF processing aspects are specified in the TS 36.100)

L1 functions are modelled for each transport channel in subclauses 6.1 and 6.2.

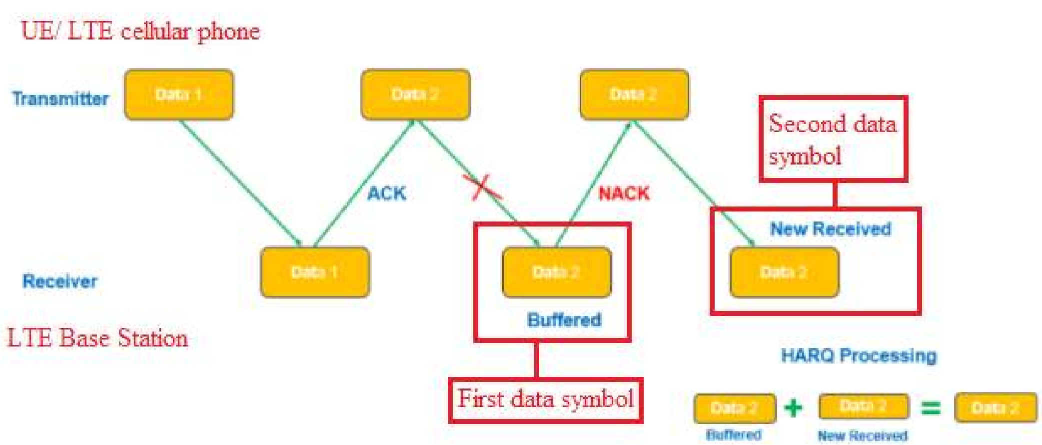
(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

38. Upon information and belief, the Accused Instrumentality, at least in its internal testing and usage, utilizes a base station which practices demodulating the received first (*e.g.*, output of modulation block performing said first modulation scheme) and second data symbols (*e.g.*, output of modulation block using a second modulation scheme) at the receiver (*e.g.*, LTE Base Station) using the first and second mappings (*e.g.*, the mappings corresponding to transmission and retransmission Modulation Coding Scheme). As shown below, the Accused

Instrumentality, at least in its internal testing and usage, utilizes a base station which practices demodulation of first (*e.g.*, output of modulation block performing said first modulation scheme) and second data symbols (*e.g.*, output of modulation block using a second modulation scheme) at the LTE Base Station using the first and second mappings *i.e.,* Modulation Coding Scheme which are distinct for transmission and Adaptive Re-transmission (*i.e.,* an Adaptive Re-transmission having a different Modulation Coding Scheme (MCS) than the one used for transmission *i.e.* first higher order modulation scheme).

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows

Hybrid Automatic Repeat Request (HARQ)



HARQ Re-transmissions Types

HARQ Re-transmissions are also of 2 types:-

- Adaptive re-transmission,
- Non-adaptive re-transmission.

Adaptive Re-transmission:

Second mapping of said higher order modulation scheme for re-transmission

Here, the transmission attributes like Modulation Coding Scheme **(MCS)**, Redundancy Version **(RV)**, **sub-carrier** on which transmission is going to occur, does not remain same during each re-transmission but are notified by the sender. These attributes can be changed according to radio channel conditions, hence, it again provides flexibility but increases overhead.

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).

Higher order modulation scheme

- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

Second transmission i.e. re-transmission based on a repeat request i.e. NAK

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

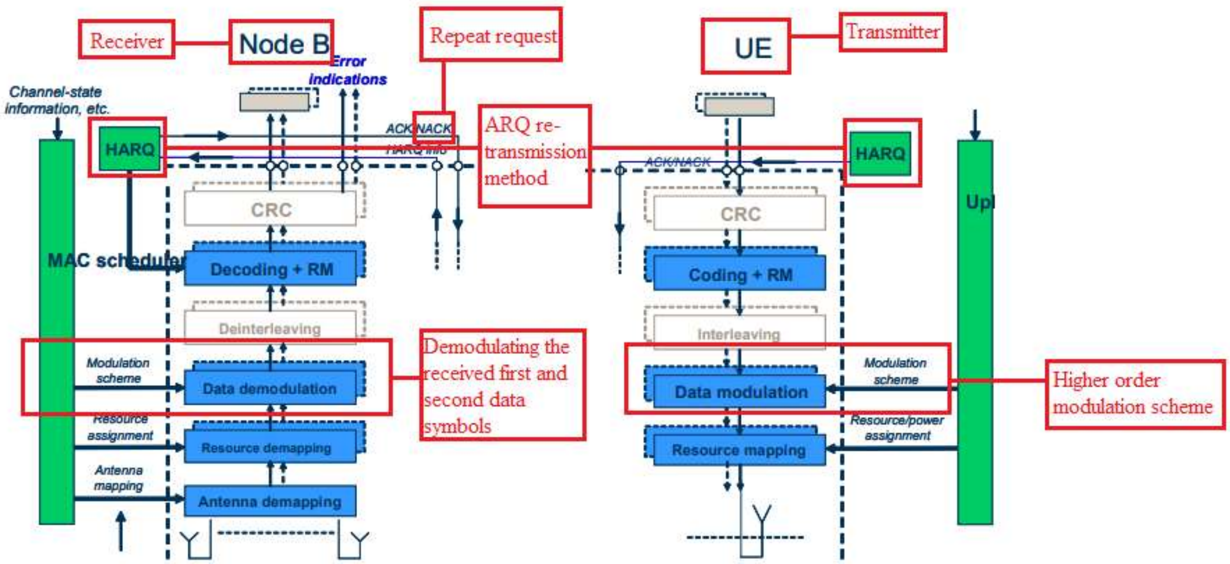


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

QAM bits per symbol

Higher order modulation scheme

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

QAM FORMATS & BIT RATES COMPARISON

MODULATION	BITS PER SYMBOL	SYMBOL RATE
BPSK	1	1 x bit rate
QPSK	2	1/2 bit rate
8PSK	3	1/3 bit rate
16QAM	4	1/4 bit rate
32QAM	5	1/5 bit rate
64QAM	6	1/6 bit rate

Respresenting more than two data bits are mapped onto one data symbol

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x = I + jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

39. Upon information and belief, the Accused Instrumentality, at least in its internal testing and usage, utilizes a base station which practices diversity combining (*e.g.*, Hybrid ARQ soft-combining) the demodulated data received over the first (*e.g.*, mapping from assigned resource blocks to the first available number of antenna ports) and second diversity branches (*e.g.*, mapping from assigned resource blocks to the later available number of antenna ports). The Accused Instrumentality, at least in its internal testing and usage, utilizes a base station which

performs a diversity combining *i.e.,* Hybrid ARQ soft-combining of data from multiple received antenna ports.

- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).
- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

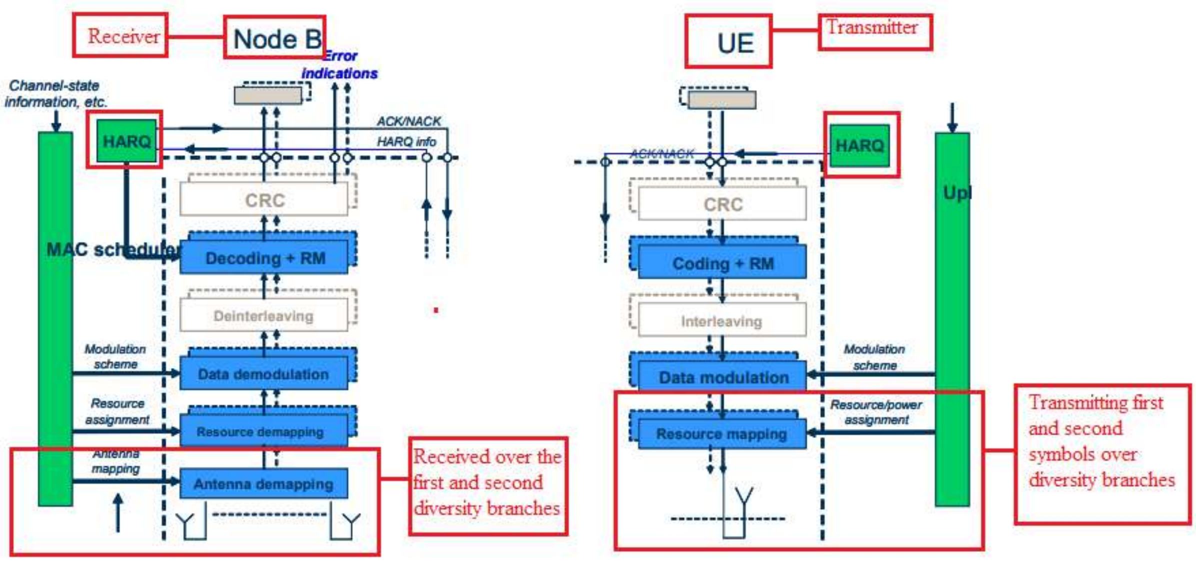


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

specific reference signals within the considered measurement frequency bandwidth. For RSRP determination the cell-specific reference signals R_0 and if available R_1 according to [8] can be used.

If receiver diversity is in use by the UE, the reported value shall be equivalent to the linear average of the power values of all diversity branches.

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

5.2 Overview of L1 functions

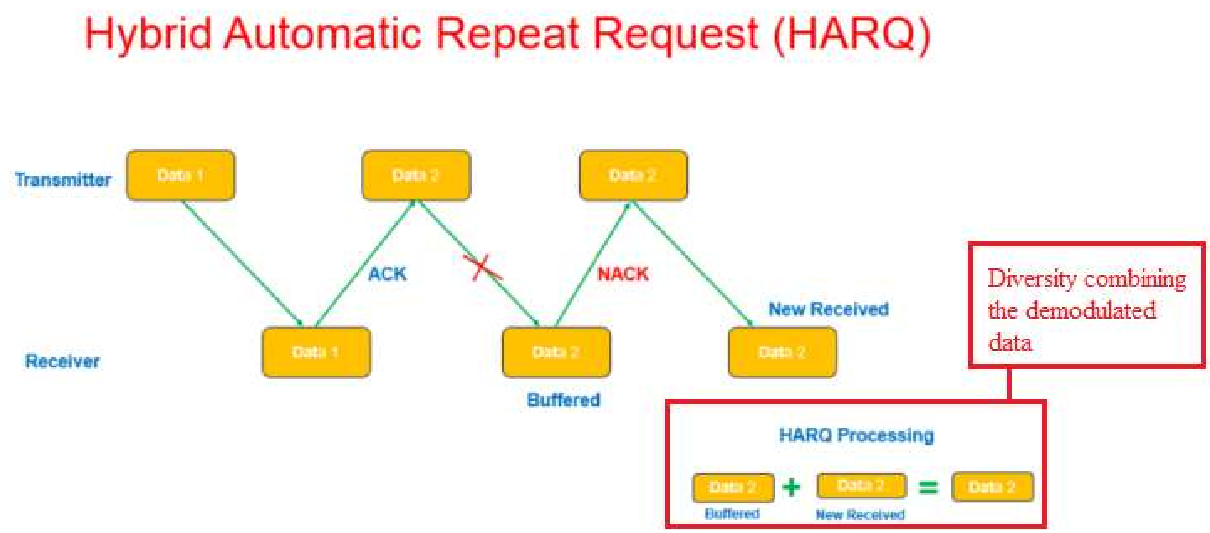
The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. The physical layer is expected to perform the following functions in order to provide the data transport service:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining   Diversity combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Beamforming
- RF processing. (Note: RF processing aspects are specified in the TS 36.100)

L1 functions are modelled for each transport channel in subclauses 6.1 and 6.2.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

40. Upon information and belief, the Accused Instrumentality, at least in its internal testing and usage, utilizes a base station receiver wherein the first and second mapping of said higher order modulation schemes are pre-stored in a memory table (*e.g.*, modulation schemes are decided by MAC Scheduler). The Accused Instrumentality performs a first higher order data modulation such as 16QAM and 64 QAM wherein has more than two data bits are mapped onto one data symbol (*i.e.,* in case of 16QAM it transmits 4 bits per symbol whereas in the case of 64QAM it transmits 6 bits per symbol). The Accused Instrumentality on repeat request *i.e.* receiving the retransmission request in the form of NAK, enables a second mapping of said higher order modulation scheme (*i.e.,* an Adaptive Re-transmission having a different Modulation Coding Scheme (MCS) than the one used for transmission *i.e.,* first higher order modulation scheme).

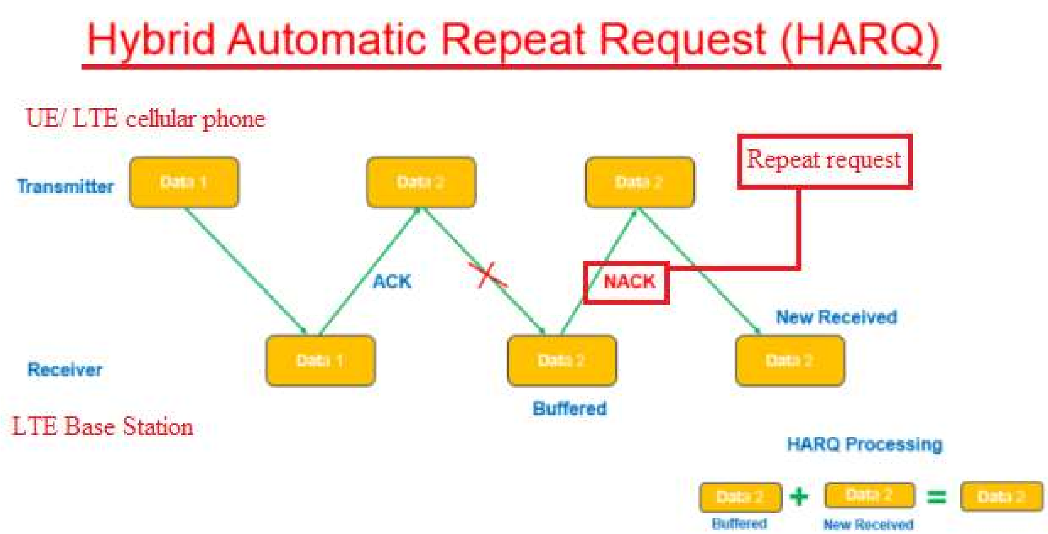
Hybrid Automatic Repeat Request (HARQ) in LTE FDD

October 18, 2018 admin Future Network Optimization, LTE, RF Basics, Tech Fundas

HARQ stands for Hybrid Automatic Repeat Request. **HARQ** = **ARQ** + **FEC** (Forward Error Correction)/Soft Combining.

ARQ refers to Automatic Repeat Request i.e. if sender doesn't receive Acknowledgement (ACK) before timeout, the receiver discards the bad packet and sender shall re-transmits the packet. ARQ procedure is illustrated below :

Soft Combining is an error correction technique in which the bad packets are not discarded but stored in a buffer. The basic idea is that 2 or more packets received with insufficient information can be combined together in such a way that total signal can be decoded. HARQ procedure is as follows



HARQ Re-transmissions Types

HARQ Re-transmissions are also of 2 types:-

- Adaptive re-transmission,
- Non-adaptive re-transmission.

Adaptive Re-transmission:

Second mapping of said higher order modulation scheme for re-transmission

Here, the transmission attributes like Modulation Coding Scheme **(MCS)**, Redundancy Version **(RV)**, **sub-carrier** on which transmission is going to occur, does not remain same during each re-transmission but are notified by the sender. These attributes can be changed according to radio channel conditions, hence, it again provides flexibility but increases overhead.

(*E.g.*, http://www.techplayon.com/hybrid-automatic-repeat-request-harq-in-lte-fdd/).

6.1 Uplink model

Data packets transmitted from a transmitter i.e. UE/ LTE cellular phone to a receiver i.e. LTE base station

6.1.1 Uplink Shared Channel

The physical-layer model for Uplink Shared Channel transmission is described based on the corresponding physical-layer-processing chain, see Figure 6.1.1. Processing steps that are relevant for the physical-layer model, e.g. in the sense that they are configurable by higher layers, are highlighted in blue. It should be noted that, in case PUSCH, the scheduling decision is partly made at the network side, if there is no blind decoding it is fully done at the network side. The uplink transmission control in the UE then configures the uplink physical-layer processing, based on uplink transport-format and resource-assignment information received on the downlink.

- **Higher-layer data passed to/from the physical layer**
- One transport block of dynamic size delivered to the physical layer once every TTI.
- **CRC and transport-block-error indication**
- Transport-block-error indication delivered to higher layers.
- **FEC and rate matching**
- Channel coding rate is implicitly given by the combination of transport block size, modulation scheme and resource assignment;

ARQ re-transmission method

- Physical layer model support of HARQ: in case of Incremental Redundancy, the corresponding Layer 2 Hybrid-ARQ process controls what redundancy version is to be used for the physical layer transmission for each TTI.
- **Interleaving**
- No control of interleaving by higher layers.
- **Data modulation**
- Modulation scheme is decided by MAC Scheduler (QPSK, 16QAM and 64QAM).

Pre-stored in a memory table

Higher order modulation scheme

- **Mapping to physical resource**
- L2-controlled resource assignment.
- **Multi-antenna processing**
- MAC Scheduler partly configures mapping from assigned resource blocks to the available number of antenna ports.
- **Support of L1 control signalling**
- Transmission of ACK/NAK and CQI feedback related to DL data transmission

Second transmission i.e. re-transmission based on a repeat request i.e. NAK

The model of Figure 6.1.1 also captures

- Transport via physical layer of Hybrid-ARQ related information (exact info is FFS) associated with the PUSCH, to the peer HARQ process at the receiver side;
- Transport via physical layer of corresponding HARQ acknowledgements to PUSCH transmitter side.

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

5.3 L1 interactions with MAC retransmission functionality

Second transmission i.e. HARQ retransmission based on a repeat request

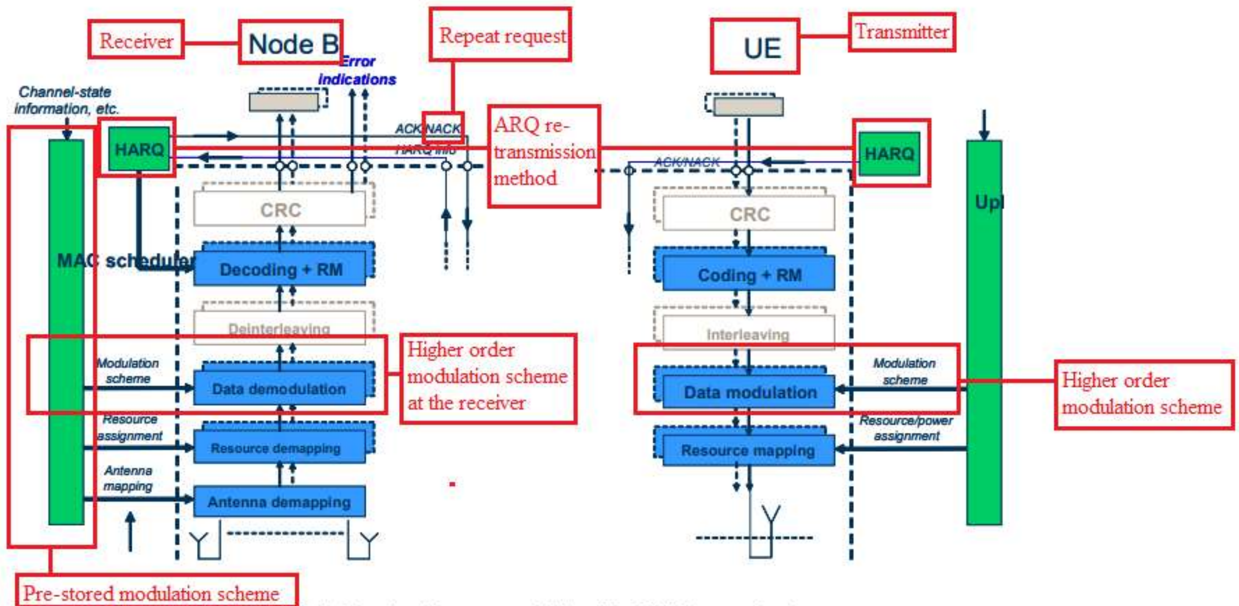


Figure 6.1.1-1: Physical-layer model for UL-SCH transmission

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136300_136399/136302/08.00.00_60/ts_136302v080000p.pdf).

QAM bits per symbol

Higher order modulation scheme

The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

QAM FORMATS & BIT RATES COMPARISON

MODULATION	BITS PER SYMBOL	SYMBOL RATE
BPSK	1	1 x bit rate
QPSK	2	1/2 bit rate
8PSK	3	1/3 bit rate
16QAM	4	1/4 bit rate
32QAM	5	1/5 bit rate
64QAM	6	1/6 bit rate

Respresenting more than two data bits are mapped onto one data symbol

(*E.g.*, https://www.electronics-notes.com/articles/radio/modulation/quadrature-amplitude-modulation-types-8qam-16qam-32qam-64qam-128qam-256qam.php).

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i), b(i+1), b(i+2), b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3)$	I	Q
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q	$b(i), b(i+1), b(i+2), b(i+3), b(i+4), b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

(*E.g.*, https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.07.00_60/ts_136211v080700p.pdf).

41. Plaintiff has been damaged as a result of Defendant's infringing conduct. Defendant is thus liable to Plaintiff for damages in an amount that adequately compensates Plaintiff for such Defendant's infringement of the '961 Patent and '622 Patent, *i.e.,* in an amount that by law cannot be less than would constitute a reasonable royalty for the use of the patented technology, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

42. On information and belief, Defendant has had at least constructive notice of the '961 Patent and '622 Patent by operation of law and marking requirements have been complied

with. Swirlate is only asserting method claims in this complaint and as such the marking requirements of 35 U.S.C. 287(a) do not apply and have thus been complied with. *Crown Packaging Technology, Inc. v. Rexam, Beverage Can Co.*, 559 F.3d 1308, 1316-1317 (Fed. Cir. 2009) ("Because Rexam asserted only the method claims of the '839 patent, the marking requirement of 35 U.S.C. 287(a) does not apply."); *Hanson v. Alpine Valley Ski Area, Inc.*, 718 F.2d 1075, 1083 (Fed.Cir. 1983) ("It is 'settled in the case law that the notice requirement of this statute does not apply where the patent is directed to a process or method." (*Quoting Bandag, Inc. v. Gerrard Tire Co.*, 704 F.2d 1578, 1581, 217 USPQ 977, 979 (Fed. Cir. 1983)); *Intellectual Ventures I LLC v. Symantec Corp.*, 2015 U.S. Dist. LEXIS 6399 *3 (D.Del. Jan. 21, 2015).

IV. <u>JURY DEMAND</u>

Plaintiff, under Rule 38 of the Federal Rules of Civil Procedure, requests a trial by jury of any issues so triable by right.

V. <u>PRAYER FOR RELIEF</u>

WHEREFORE, Plaintiff respectfully requests that the Court find in its favor and against Defendant, and that the Court grant Plaintiff the following relief:

a. Judgment that one or more claims of United States Patent No. 7,154,961 have been infringed, either literally and/or under the doctrine of equivalents, by Defendant;

b. Judgment that one or more claims of United States Patent No. 7,567,622 have been infringed, either literally and/or under the doctrine of equivalents, by Defendant;

c. Judgment that Defendant account for and pay to Plaintiff all damages to and costs incurred by Plaintiff because of Defendant's infringing activities and other conduct complained of herein;

d. That Plaintiff be granted pre-judgment and post-judgment interest on the damages caused by Defendant's infringing activities and other conduct complained of herein;

e. That Plaintiff be granted such other and further relief as the Court may deem just and proper under the circumstances.

November 29, 2022

DIRECTION IP LAW

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