IEEE STANDARDS ASSOCIATION

IEEE

tf1_1610_sestito_3gpp-split-options_1

Vincenzo Sestito

SM Optics

Compliance with IEEE Standards Policies and Procedures

Subclause 5.2.1 of the *IEEE-SA Standards Board Bylaws* states, "While participating in IEEE standards development activities, all participants...shall act in accordance with all applicable laws (nation-based and international), the IEEE Code of Ethics, and with IEEE Standards policies and procedures."

The contributor acknowledges and accepts that this contribution is subject to

- The IEEE Standards copyright policy as stated in the *IEEE-SA Standards Board Bylaws*, section 7, http://standards.ieee.org/develop/policies/bylaws/sect6-7.html#7, and the *IEEE-SA Standards Board Operations Manual*, section 6.1, http://standards.ieee.org/develop/policies/opman/sect6.html
- The IEEE Standards patent policy as stated in the *IEEE-SA Standards Board Bylaws*, section 6, http://standards.ieee.org/guides/bylaws/sect6-7.html#6, and the *IEEE-SA Standards Board Operations Manual*, section 6.3, http://standards.ieee.org/develop/policies/opman/sect6.html

IEEE 1914.1 TF
NGFI
Bomin Li (bomin.li@comcores.com)

tf1_1610_sestito_3gpp-split-options_1			
Date: 2016-10-17			
Author(s):			
Name	**Affiliation**	**Phone [optional]**	**Email [optional]**
Vincenzo Sestito	SM Optics	+300399064371	vincenzo.sestito@sm-optics.com

Contents

- Summary of positions on CU-DU functional split (including TR38.801 v0.4.0 outcomes and August 2016 contributions)
- Transport requirements view (addressed by TR38.801 and CMCC, NTT, ZTE contributions)

3GPP TR 38.801 V0.4.0 on CU-DU split_1

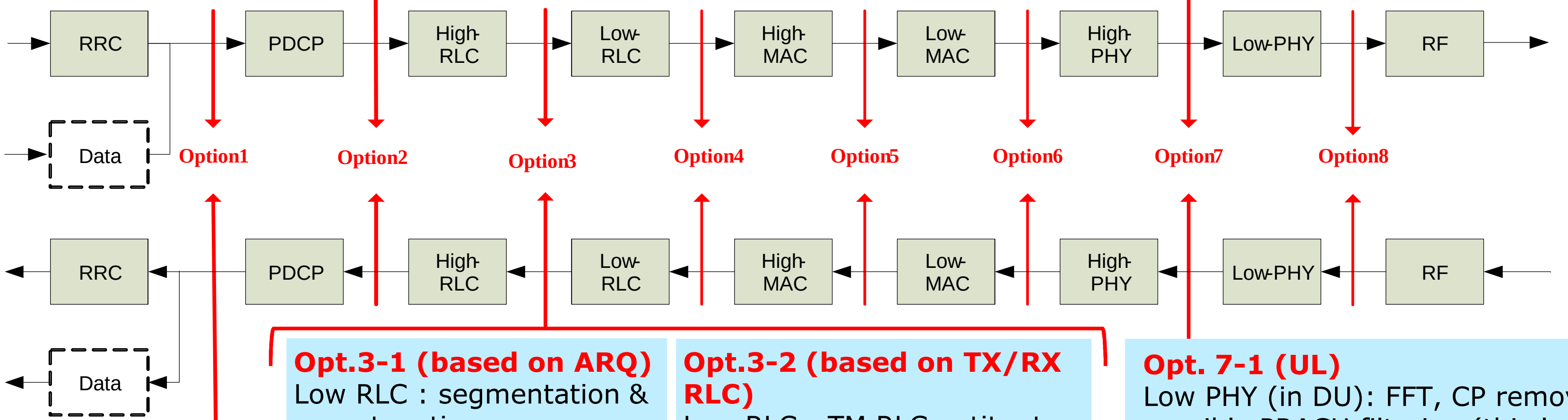
SOURCE	PROMOTED SPLIT	RELATED COMMENTS
3GPP TR38801 v0.4.0	8 split options described. Option 2 (PDCP/RLC) considered as most straightforward option since already considered by standard. Example of BW figures for different mobile BS configuration provided	Fundamentals for PDCP-RLC split already standardized (see LTE Dual Connectivity). Two variants described for option 3 (High RLC/Low RLC) on the base of "real time" / "non real time" tasks; namely, 3-1, 3-2 (further details on next slide) Two variants described for option 7 (High/Low PHY); namely 7-1, 7-2 (further details on next slide)

Open points on split options (from Editor's Note):
(1) How many splits will be specified and supported by open interfaces?
(2) Will the tight LTE/NR interworking case effect the number of functional split options?
(3) What is the granularity of the Centralized Unit – Distributed Unit functional split?
(4) What is the reconfiguration dynamicity of the network functional split?

3GPP TR 38.801 V0.4.0 on CU-DU split_2

Opt. 2
It allows traffic aggregation (from NR/eLTE) and management of traffic load (between BR/eLTE points).
Similar to 3C in LTE DC.

Opt. 7-1 (DL)
Low PHY (in DU): iFFT, CP addition
High PHY (in CU): remaining functions.
Opt. 7-2 (DL)
Low PHY (in DU): iFFT, CP addition, resource mapping and pre-coding.
High PHY (in CU): remaining functions.



Opt. 1
Similar to 1A architecture in DC

Opt.3-1 (based on ARQ)
Low RLC : segmentation & concatenation
High RLC: ARQ & re-ordering
Compared to Opt. 2:
More centralization/pooling gain (due to centralized ARQ)
Reduced processing/ buffers in DU (due to centralized ARQ)

Opt.3-2 (based on TX/RX RLC)
Low RLC : TM RLC entity, tx UM TLC entity, tx AM, rx AM routing function
High RLC: TM RLC entity, rx UM RLC entity, rx AM (no routing function)

Opt. 7-1 (UL)
Low PHY (in DU): FFT, CP removal, possibly PRACH filtering (this last is FFS).
High PHY (in CU): remaining functions
Opt. 7-2 (UL)
Low PHY (in DU): FFT, CP removal, resource de-mapping and possibly pre-filtering (this last is FFS).
High PHY (in CU): remaining functions.

Summary of contributions on CU-DU split_1

SOURCE	PROMOTED SPLIT	RELATED COMMENTS
ATT R3-161773 R3-162004 R3-162063	2 (PDCP/RLC) - 3 (intra-RLC) - 7 (intra-PHY with asymmetrical UL/DL)	Option 2 is the most straightforward split option to standardize and the incremental effort to standardize this option should be relatively small (already considered by 3GPP for LTE DC function) Option 3 may have advantages over Option 2 in the form of better resiliency against unreliable transport and better flow control (i.e., ARQ across network) Option 7 may need to be asymmetric in the downlink and uplink in order to support advanced receivers for NR, not preclude joint processing techniques for the uplink or downlink, and have reasonable transport bandwidth requirement
CATT R3-162003	No split promoted (option 3 detailed more than other)	Flexible split configuration endorsed
CMCC R3-161810 R3-161811 R3-161812 R3-161813 R3-162005	3 (intra-RLC) – 5 (intra-MAC) - 7 (intra PHY, with a-b-c flavours) BW and latency figures provided for each split (useful for transport req.s)	Option 3 is more suitable for high throughput over air interface Option 5 is more suitable for real-time flexible controlling and centralized scheduling Option 7 is more suitable for seamless multi-antenna coverage Based on CP and UP traffics characteristics, option 3 and 5 respectively more suitable for UP and CP
Ericsson R3-161898	No split promoted; how to address RAN architecture (splits) is considered	The choice of a RAN architecture depends on offered services, user density, load demand and transport network performance in the RAN service area. The RAN architecture specified in 3GPP shall provide flexibility to implementations to adapt to varying conditions with the best tailored distributed RAN architecture that can fulfil use case requirements
Huawei R3-161747	2 (PDCP/RLC)	Same as ATT. Besides, basic splitting option, since requiring lower bandwidth and looser delay than other lower layer splitting options – Centralized mobility and security keys – PDCP as a possible convergence layer between LTE and NR (lower layers in DU's)

Summary of contributions on CU-DU split_2

SOURCE	PROMOTED SPLIT	RELATED COMMENTS
Intel R3-161571 R3-161572 R3-161573 R3-161576 R3-162002 R3-162062	No split promoted; 5 (intra-MAC), 6 (MAC/PHY) and 7 (intra-PHY I and II) analyzed Considerations on the need to identify/classify transport network solutions (uw and fiber based) on the base of BW and latency performances, to be used for functional split evaluations	Option 5 - Centralized MAC scheduler enables support for various features such as CoMP, CA, and DC with a multi-cell view. NR stringent HARQ timing requirements can be hard to fulfill if HARQ is implemented in the CU. Performing HARQ operation in DUs instead of CU can reduce latency and processing requirements in both UE and network. Not only the HARQ component, but also the cell-specific MAC functionalities such as random access control, maintenance on C-RNTI, uplink timing alignment, etc. can be moved to DU and thus reduce pressure on the transport network requirement. Some MAC functionalities (such as HARQ and random access control) are closely coupled with dynamic resource allocation. Therefore, at least some DU-level resource scheduling may be inevitable. Option 6 - Centralized MAC scheduler enables support for various features such as CoMP, CA, and DC with a multi-cell view. The MAC-PHY protocol split option allows an independent software/hardware evolution in CU and DU. Moreover, the CU's higher processing capability will enable large-scale processing for better inter-cell interference coordination, load management, real-time performance adaptation for 5G evolution. The centralized MAC scheduler in CU requires multiple interactions with the PHY layer in each DU. In order to further evaluate this option, it is important to understand how the latency affects centralized scheduling decisions. Option 7-I (done just above FFT/I-FFT) - CBR and peak rate reduceable by removing CP and w/ frequency compression procedures (from 4x to 10x reduction mentioned) Option 7-II – users load dependent; easier compression than 7-I (peak rate reduction)

Summary of contributions on CU-DU split_3

SOURCE	PROMOTED SPLIT	RELATED COMMENTS
InterDigital R3-161762 R3-161763	No split promoted, but two splits classifications addressed: «Dual Connectivity related" (with and without ARQ), see Options 1, 2, 3, 4 "Centralized Scheduling related" (with/without centralized PHY functions), see Options 5, 6, 7, 8	«Dual connectivity options» imply centralized RRM functions like CAC, load balancing etc. "Centralized Scheduling options" imply centralized RRM functions like CAC, load balancing etc. + Centralized MAC scheduling allowing for coordinated scheduling techniques like CoMP (this is particularly useful when very low latency transport is available – low latency transport necessary with centralized PHY functions)
KT R3-161777	2 (PDCP/RLC) and 3 (intra RLC)	Option 3 should be split in terms of Non-RT and RT sub-functions of RLC protocol, respectively. CU should have required common protocol functions to flexibly accommodate different DUs that have different protocol functions. Open fronthaul interface between CU and DU should support the dynamic configuration of multiple functional splits.
Nokia_ASB R3-161628	3 (intra RLC) - Also analizyed both 2 and 3 based in terms of «real time» (to be placed at DU) or «non real time functions» (to be placed at CU)	Option 3 (with ARQ at CU) implies centralization gains: ARQ is an NRT function and expensive in terms of memory and processing power - The failure over transport network is also recovered using the end-end ARQ mechanism at CU - DUs without functions of RLC can handle more connected mode UEs as there is no RLC state information stored and hence no need for UE context - Reduced processing and buffer requirements in DU due to absence of ARQ protocol. CON's: more latency sensitive than the split with ARQ in DU. Re-transmissions are susceptible to transport network latency
NTT DOCOMO R3-161824	Addressing 2/3 and 6/7 to be studied BW and latency figures provided for splits 6, 7a/b and 8 (useful for transport req.s)	2 split options to be chosen, one for high performance transport (see opt.s 6 or 7), huge bandwidth limited delay; and the other one for low performance transport (see opt.s 2 or 3), limited bandwidth, high delay.

Summary of contributions on CU-DU split_4

SOURCE	PROMOTED SPLIT	RELATED COMMENTS
Samsung R3-162007	No specific split promoted	Just different architecture with simple CU to DU (based on different FI's) or CU to DU1 to DU2 connectivity (segments connectivity based on different req.s /split options)
ZTE R3-161784 R3-161785	Proposed relationship between split options and 5G applications Provided BW figures for the different split options (useful for trasnport req.s)	Proposed requirements table for the 8 split options identified (addressing BW, latency, 5G application match, NFV support, multi RAT support, CAPEX/OPEX reduction). Based on the analisys, identified the following match: Option 1 is suitable for URLLC. Option 1, 2, 3 are suitable for mMTC. All options are suitable for eMBB

TR38.801 v0.40 on transport network aspects

Examples of required bitrate on a transmission link for one possible PHY/RF based RAN architecture split

Number of Antenna Ports	Frequency System Bandwidth			
	10 MHz	**20 MHz**	**200 MHz**	**1GHz**
2	1Gbps	2Gbps	20Gbps	100Gbps
8	4Gbps	8Gbps	80Gbps	400Gbps
64	32Gbps	64Gbps	640Gbps	3200Gbps
256	128Gbps	256Gbps	2560Gbps	12800Gbps

Remark: Peak bitrate requirement on a transmission link = Number of BS antenna elements * Sampling frequency (proportional to System bandwidth) * bit width (per sample) + overhead

CMCC on transport req.s (R3-161813)

Assuming LTE as a reference, peak rate of DL and UL are 150Mbps and 50Mbps.

For 5G, the following assumptions are considered as baselines:

- bandwidth is 100MHz;
- number of layers for UL / DL are all 8;
- modulation order is 64QAM for UL and 256QAM for DL in full load.

[1] Description of the split option
[2] Driving feature / use-case requiring a certain split option

Protocol Split option[1]	Required bandwidth	Max. allowed one way latency [ms]	Delay critical feature[2]	Comment
Option 1	DL: 4Gb/s UL: 3Gb/s	10ms		
Option 2	DL: 4016Mb/s UL:3024 Mb/s	1.5~10ms		
Option 3	lower than option 2 for UL/DL	1.5~10ms		
Option 4	DL:5226.7Mb/s UL:4500Mb/s	approximate 100us		
Option 5	DL: 5626.7Mb/s UL: 7140 Mb/s	hundreds of microseconds		
Option 6	DL: 5626.7Mb/s UL:7140 Mb/s	250us		
Option 7a	DL:9.8Gb/s UL:15.2Gb/s	250us		
Option 7b	DL:9.2Gb/s UL:60.4 Gb/s	250us		
Option 7c	DL:9.8Gb/s UL:60.4Gb/s	250us		
Option 8	DL:157.3Gb/s. UL: 157.3Gb/s	250us		

NTT on transport req.s (R3-161824)

The required FH BW for DL assuming following:
- LTE (for reference): 20MHz, 2 Ant., 2layer-MIMO, 64QAM

- NR (to be confirmed by RAN1): 20MHz, 8layer-MIMO, 256QAM

Option7A refers to intra-PHY split (precoder and below in DU) and Option7B refers to intra-PHY split (IFFT and below in DU)

Bandwidth	Tx Ant.	The required FH BW for DL[Gbps]					
		Option8		Option7B		Option7A	Option6
		w/o H-BF	w/ H-BF	w/o H-BF	w/ H-BF		
20MHz	2	1.8432	-	0.504	-	0.350	0.150
100MHz	8	29.4912	-	10.08	-	7	4
200MHz		58.9824		20.16		14	8
400MHz		117.9648		40.32		28	16
800MHz		235.9296		80.64		56	32
100MHz	64	235.9296	29.4912	80.64	10.08	7	4
200MHz		471.8592	58.9824	161.28	20.16	14	8
400MHz		943.7184	117.9648	322.56	40.32	28	16
800MHz		1887.4368	235.9296	645.12	80.64	56	32
100MHz	256	943.7184	29.4912	322.56	10.08	7	4
200MHz		1887.4368	58.9824	645.12	20.16	14	8
400MHz		3774.8736	117.9648	1290.24	40.32	28	16
800MHz		7549.7472	235.9296	2580.48	80.64	56	32

ZTE on transport req.s_1 (R3-161784)

1 Description of split option
2 The maximum allowed latency from CU to DU or DU to CU without the effect on radio protocol layer function and performance
3 Driving feature/use-case requiring a certain split option

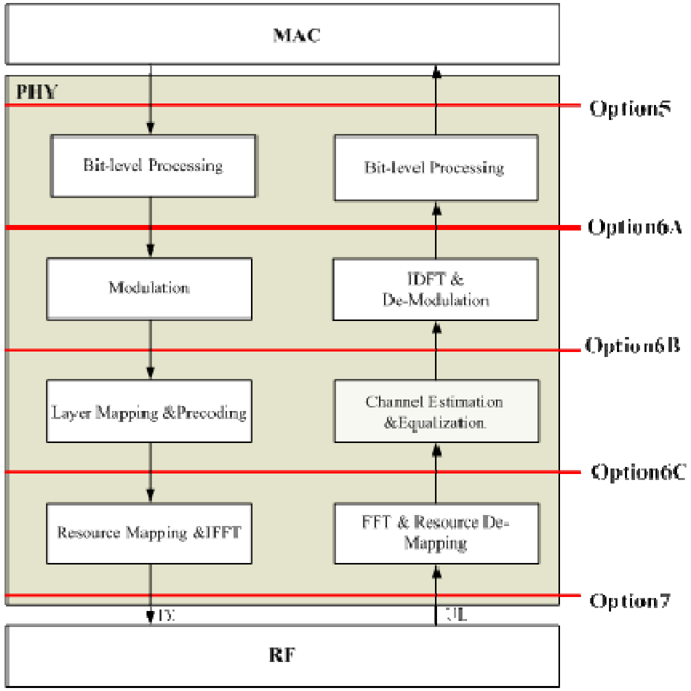
Protocol Split option[1]	Required bandwidth	Max. allowed one way latency [ms] [2]	Delay critical feature[3]	Other aspects		
				Support of multi-RAT (e.g. LTE, WLAN)	Support of NFV	CAPEX and OPEX
Option 1	[>30 Gbps] (Corresponding to 1GHz air bandwidth)	Hunderds of ms	[Dual Connectivity 1A Architecture] [URLLC] [mMTC] [eMBB]	- Support of multi-RAT	- Proper to realize NFV	- As to wireless device, highest cost for DU if deployed outdoor - As to transport deployment, low transport requirement leading to low cost (for example, Gigabit Ethernet)
Option 2	[>30 Gbps] (Corresponding to 1GHz air bandwidth)	[>20ms]	[Dual Connectivity 3C Architecture] [mMTC] [eMBB]	- Support of multi-RAT	- Proper to realize NFV	- As to wireless device, higher cost for DU if deployed outdoor - As to transport deployment , low transport requirement leading to low cost (for example, Gigabit Ethernet)
Option 3	[>30 Gbps] (Corresponding to 1GHz air bandwidth)	[>10 ms]	[mMTC] [eMBB]	- Support of multi-RAT	- Proper to realize NFV	- As to wireless device, higher cost for DU if deployed outdoor - As to transport deployment , low transport requirement leading to low cost (for example, bare optical fiber)
Option 4	[>30 Gbps] (Corresponding to 1GHz air bandwidth)	[<1 ms]	[eMBB]	- Need to be studied	- Need to be studied	- As to wireless device, high cost for DU if deployed outdoor - As to transport deployment , high transport requirement leading to high cost (for example, OTN)
Option 5	[>30 Gbps] (Corresponding to 1GHz air bandwidth)	[<1 ms]	[eMBB]	- Need to be studied	- Need to be studied	- As to wireless device, high cost for DU if deployed outdoor - As to transport deployment , high transport requirement leading to high cost (for example, OTN)

ZTE on transport req.s_2 (R3-161784)

Option6	[>40 Gbps] (Corresponding to 1GHz air bandwidth)	[<0.2 ms]	[Centralized scheduling] [Carrier aggregation] [DL COMP] [part UL COMP] [eMBB] [URLLC]	- NO	- Need to be studied	- As to wireless device, low cost for DU if deployed outdoor - As to transport deployment , high transport requirement leading to high cost (for example, OTN)
Option 7	[>50 Gbps] (Corresponding to 1GHz air bandwidth, 256 Antenna Ports)	[<0.2 ms]	[Centralized scheduling] [Carrier aggregation] [DL COMP] [part UL COMP] [eMBB] [URLLC]	- NO	- Need to be studied	- As to wireless device, low cost for DU if deployed outdoor - As to transport deployment , high transport requirement leading to high cost (for example, OTN)
Option 8	[>10 Tbps] (Corresponding to 1GHz air bandwidth, 256 Antenna Ports)	[<0.2 ms]	[Centralized scheduling] [Carrier aggregation] [DL COMP] [UL COMP] [eMBB] [URLLC]	- NO	- NO	- As to wireless device, lowest cost for DU if deployed outdoor - As to transport deployment , highest transport requirement leading to high cost (for example, CPRI)

ZTE on peak rate req.s_1 (R3-161785)

Intra-PHY splits considered in 161785
(NOTE: 3GPP numbering-1)



DL required bitrates on a transmission link

Function Split Options between central and distributed unit	Frequency System Bandwidth			
	10 MHz	20 MHz	200 MHz	1GHz
1	0.38 Gbps	0.76 Gbps	7.6 Gbps	38 Gbps
2	0.36 Gbps	0.72 Gbps	7.2 Gbps	36Gbps
3	0.36 Gbps	0.72 Gbps	7.2 Gbps	36Gbps
4	0.36 Gbps	0.72 Gbps	7.2 Gbps	36Gbps
5	0.4 Gbps	0.8 Gbps	8 Gbps	40Gbps
6A	0.55Gbps	1.1Gbps	11 Gbps	54Gbps
6B	2.2Gbps	4.3 Gbps	43 Gbps	215Gbps

ZTE on peak rate req.s_2 (R3-161785)

Number of Antenna Ports	Frequency System Bandwidth			
	10 MHz	20 MHz	200 MHz	1GHz
2	0.55 Gbps	1.1 Gbps	11 Gbps	54Gbps
8	2.2 Gbps	4.3 Gbps	43 Gbps	215Gbps
64	17.2 Gbps	34.4 Gbps	344 Gbps	1720 Gbps
256	69Gbps	138 Gbps	1376 Gbps	6881 Gbps

DL required bitrates on a transmission link for Option 6C

Number of Antenna Ports	Frequency System Bandwidth			
	10 MHz	20 MHz	200 MHz	1GHz
2	1Gbps	2Gbps	20Gbps	100Gbps
8	4Gbps	8Gbps	80Gbps	400Gbps
64	32Gbps	64Gbps	640Gbps	3200Gbps
256	128Gbps	256Gbps	2560Gbps	12800Gbps

DL required bitrates on a transmission link for Option 7 (Option 8 in 3GPP references)

ZTE on peak rate req.s_3 (R3-161785)

Function Split Options between central and distributed unit	Frequency System Bandwidth			
	10 MHz	20 MHz	200 MHz	1GHz
1	0.19 Gbps	0.37 Gbps	3.7 Gbps	18.5 Gbps
2	0.18 Gbps	0.35Gbps	3.5 Gbps	17.6Gbps
3	0.18 Gbps	0.35Gbps	3.5 Gbps	17.6Gbps
4	0.18 Gbps	0.35Gbps	3.5 Gbps	17.6Gbps
5	0.2 Gbps	0.39 Gbps	3.9 Gbps	19.6 Gbps
6A	1.84 Gbps	3.6 Gbps	36 Gbps	184 Gbps
6B	0.92 Gbps	1.84 Gbps	18.4 Gbps	92.2 Gbps

UL required bitrates on a transmission link

ZTE on peak rate req.s_4 (R3-161785)

Number of Antenna Ports	Frequency System Bandwidth			
	10 MHz	**20 MHz**	**200 MHz**	**1GHz**
2	0.55 Gbps	1.1 Gbps	11 Gbps	54Gbps
8	2.2 Gbps	4.3 Gbps	43 Gbps	215Gbps
64	17.2 Gbps	34.4 Gbps	344 Gbps	1720 Gbps
256	69Gbps	138 Gbps	1376 Gbps	6881 Gbps

UL required bitrates on a transmission link for Option 6C

Number of Antenna Ports	Frequency System Bandwidth			
	10 MHz	**20 MHz**	**200 MHz**	**1GHz**
2	1Gbps	2Gbps	20Gbps	100Gbps
8	4Gbps	8Gbps	80Gbps	400Gbps
64	32Gbps	64Gbps	640Gbps	3200Gbps
256	128Gbps	256Gbps	2560Gbps	12800Gbps

UL required bitrates on a transmission link for Option 7 (Option 8 in 3GPP references)