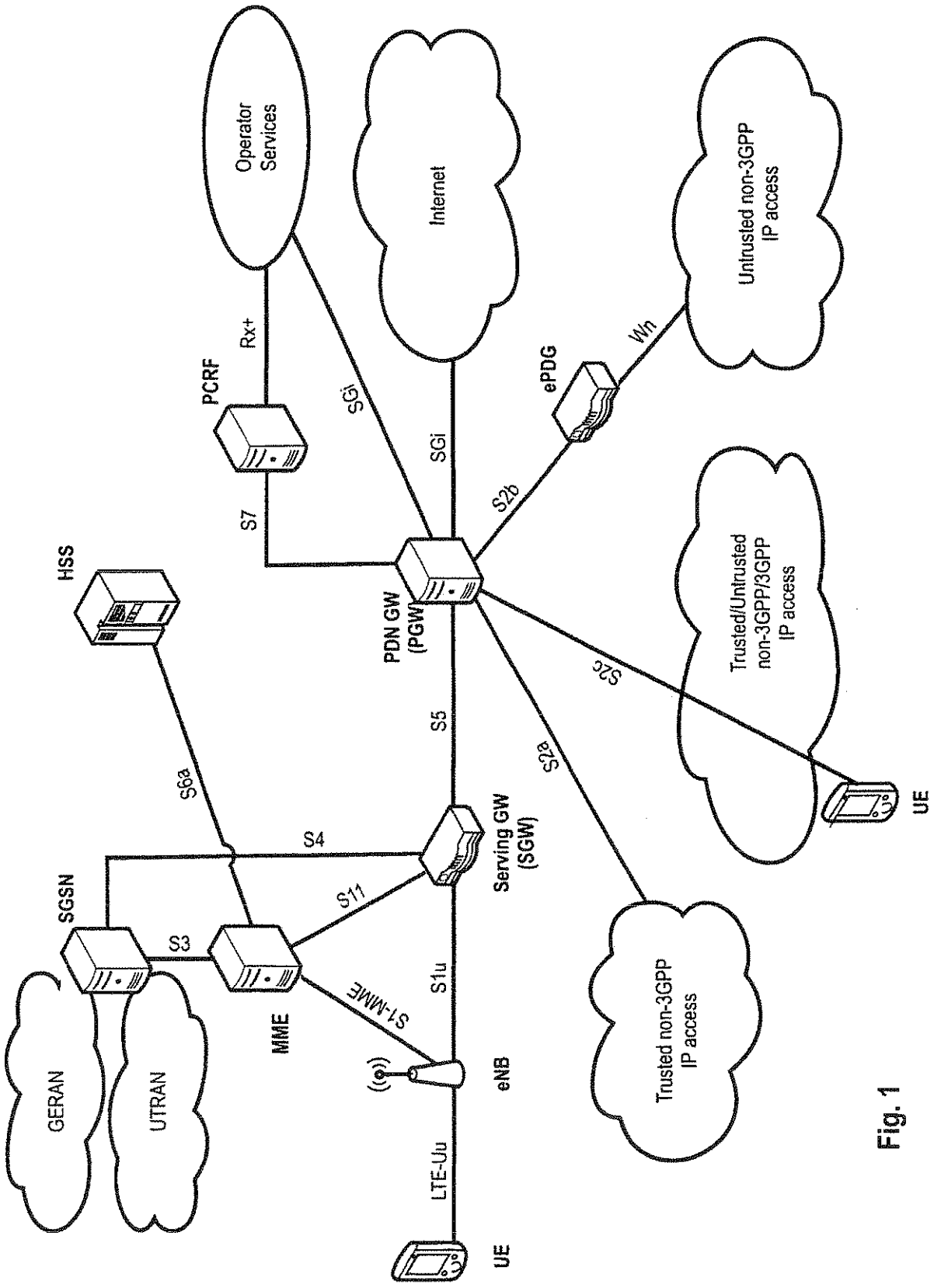

Operator Services
Internet
Untrusted non-3GPP IP access
Rx+
PCRF
SGi
SGi
ePDG
Wn
S7
S2b
HSS
PDN GW (PGW)
Trusted/Untrusted non-3GPP/3GPP IP access
S2c
S5
S6a
S2a
S4
Serving GW (SGW)
UE
S11
SGSN
S3
S1u
S1-MME
MME
GERAN
UTRAN
eNB
Trusted non-3GPP IP access
LTE-Uu
UE

Fig. 1

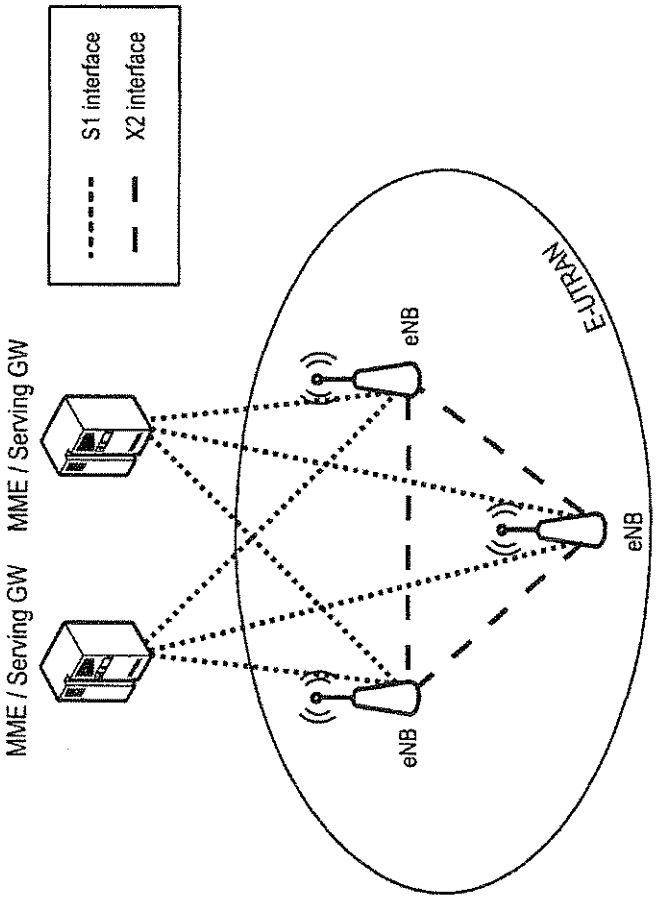

S1 interface
X2 interface
MME / Serving GW
MME / Serving GW
eNB
eNB
eNB
E-UTRAN

Fig. 2

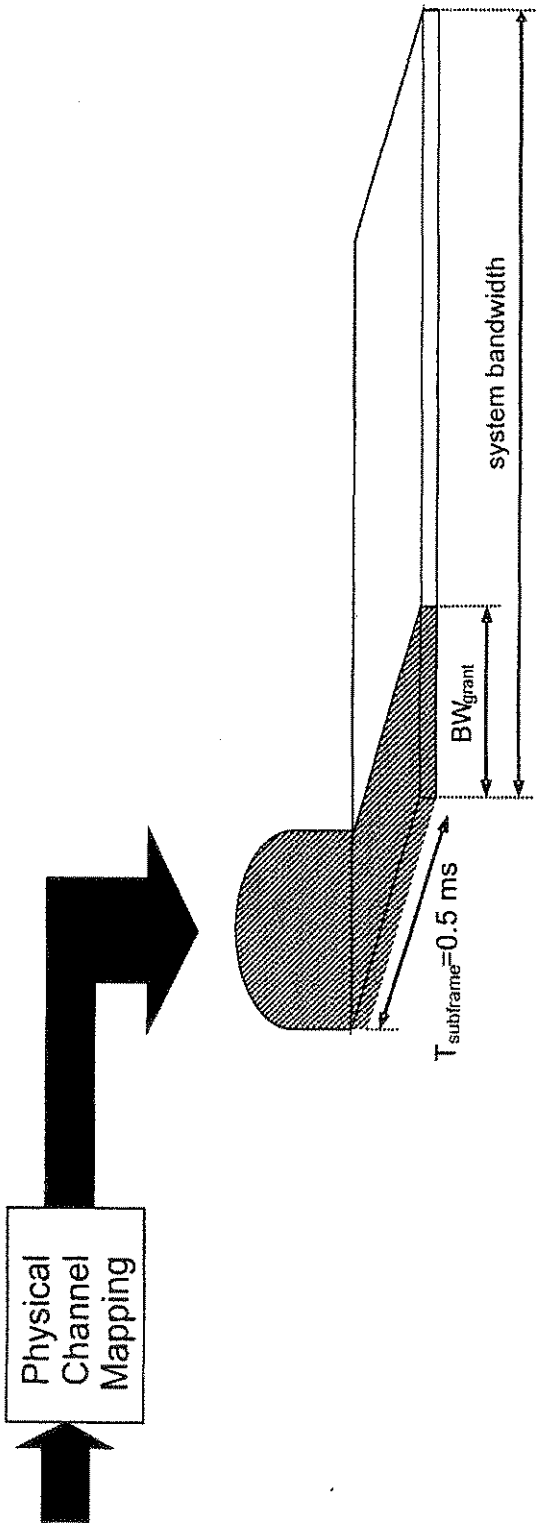

Physical Channel Mapping
system bandwidth
BW_{grant}
$T_{subframe}$=0.5 ms

Fig. 3

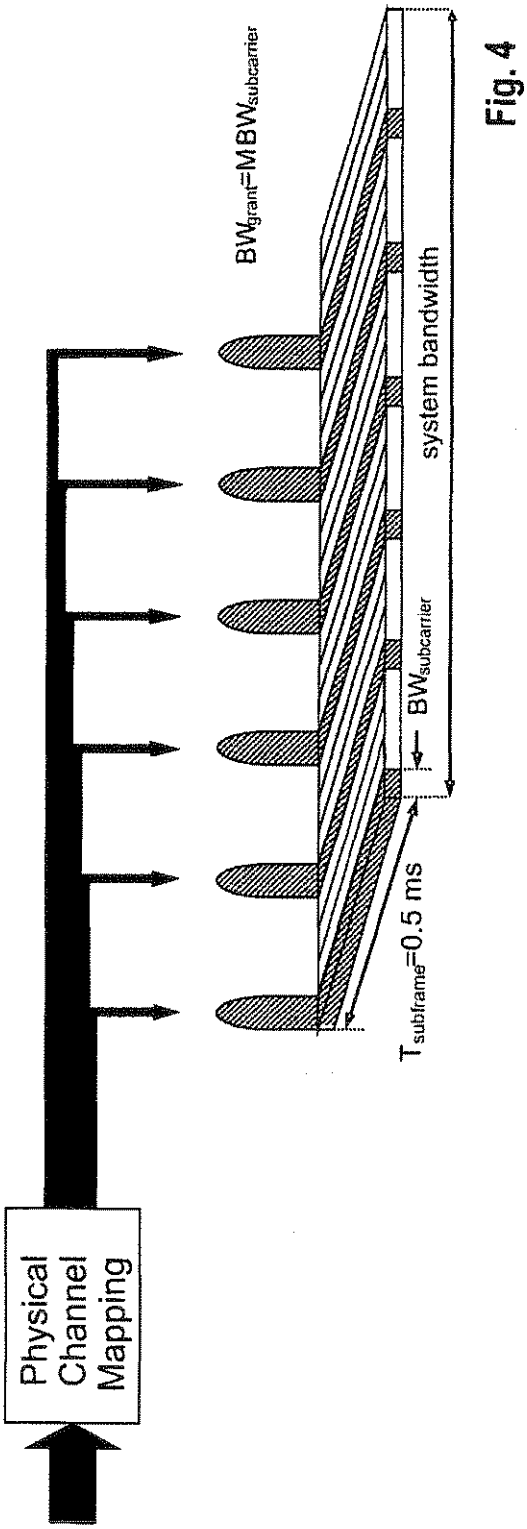

Physical Channel Mapping
BW_{grant}=M $BW_{subcarrier}$
system bandwidth
$BW_{subcarrier}$
$T_{subframe}$=0.5 ms

Fig. 4

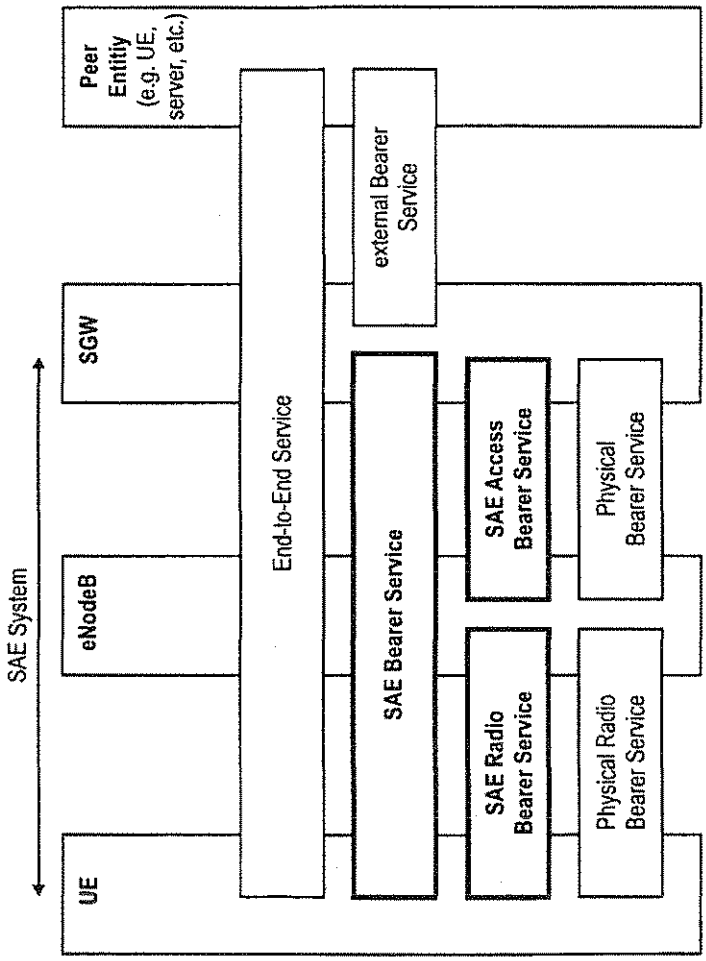

SAE System
UE
eNodeB
SGW
Peer Entitiy (e.g. UE, server, etc.)
End-to-End Service
external Bearer Service
SAE Bearer Service
SAE Access Bearer Service
Physical Bearer Service
SAE Radio Bearer Service
Physical Radio Bearer Service

Fig. 5

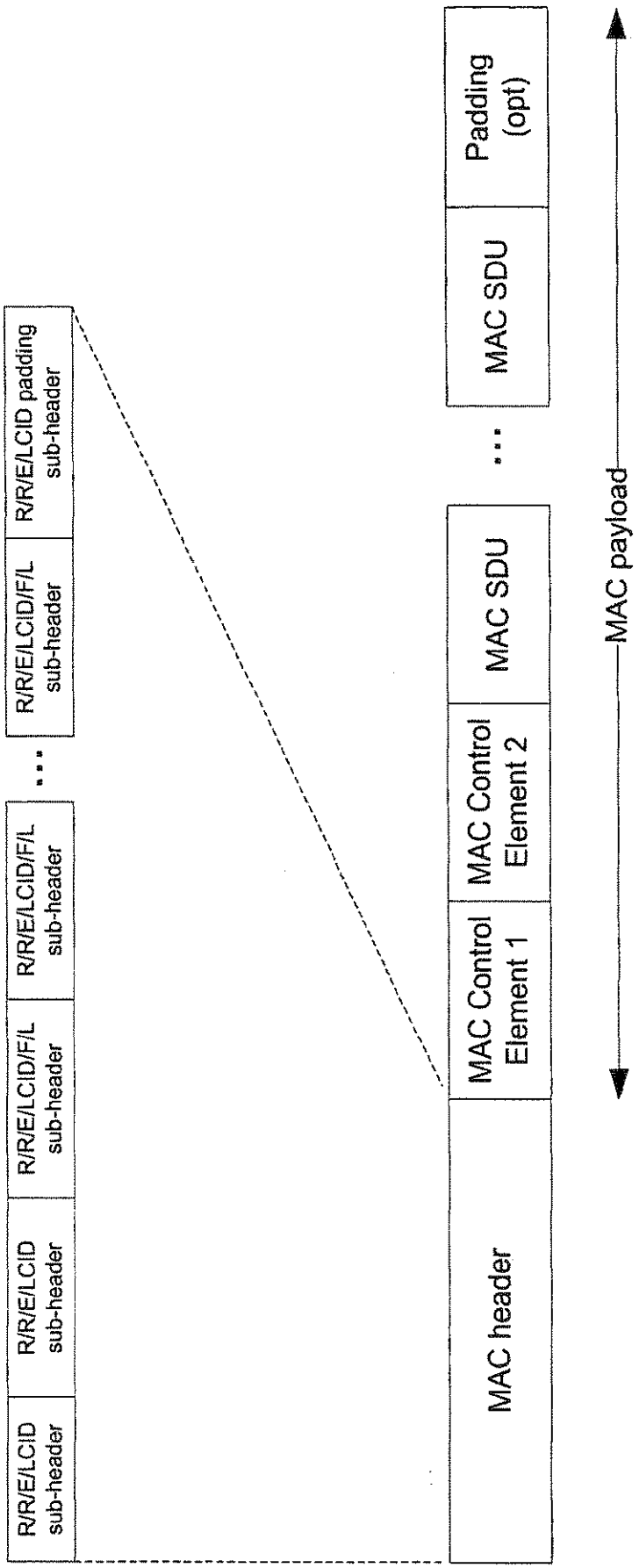

R/R/E/LCID sub-header
R/R/E/LCID sub-header
R/R/E/LCID/F/L sub-header
R/R/E/LCID/F/L sub-header
...
R/R/E/LCID/F/L sub-header
R/R/E/LCID padding sub-header
MAC header
MAC Control Element 1
MAC Control Element 2
MAC SDU
...
MAC SDU
Padding (opt)
MAC payload

Fig. 6

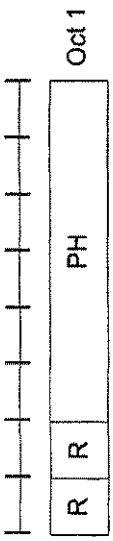

R
R
PH
Oct 1

Fig. 7

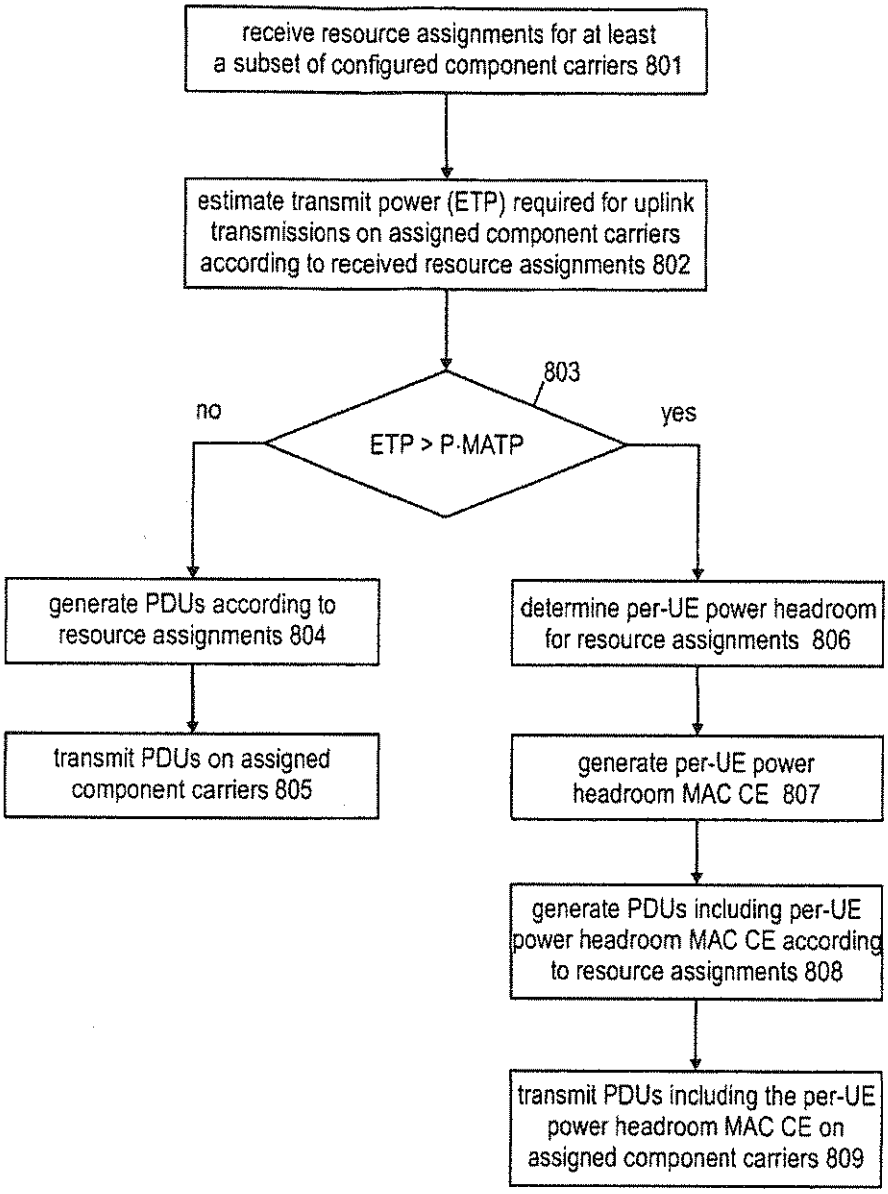

receive resource assignments for at least a subset of configured component carriers 801
estimate transmit power (ETP) required for uplink transmissions on assigned component carriers according to received resource assignments 802
803
ETP > P·MATP
no
yes
generate PDUs according to resource assignments 804
transmit PDUs on assigned component carriers 805
determine per-UE power headroom for resource assignments 806
generate per-UE power headroom MAC CE 807
generate PDUs including per-UE power headroom MAC CE according to resource assignments 808
transmit PDUs including the per-UE power headroom MAC CE on assigned component carriers 809

Fig. 8

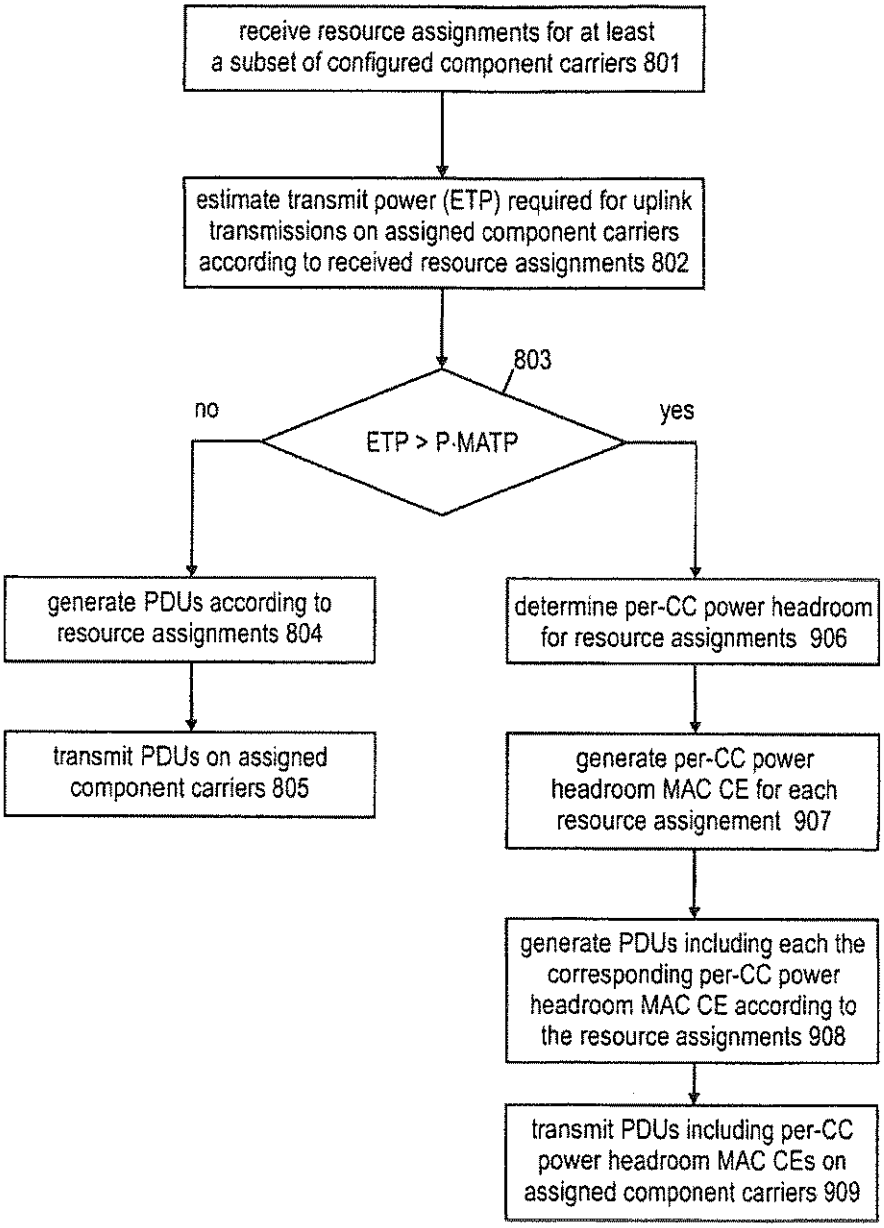

receive resource assignments for at least a subset of configured component carriers 801
estimate transmit power (ETP) required for uplink transmissions on assigned component carriers according to received resource assignments 802
803
ETP > P-MATP
no
yes
generate PDUs according to resource assignments 804
transmit PDUs on assigned component carriers 805
determine per-CC power headroom for resource assignments 906
generate per-CC power headroom MAC CE for each resource assignement 907
generate PDUs including each the corresponding per-CC power headroom MAC CE according to the resource assignments 908
transmit PDUs including per-CC power headroom MAC CEs on assigned component carriers 909

Fig. 9

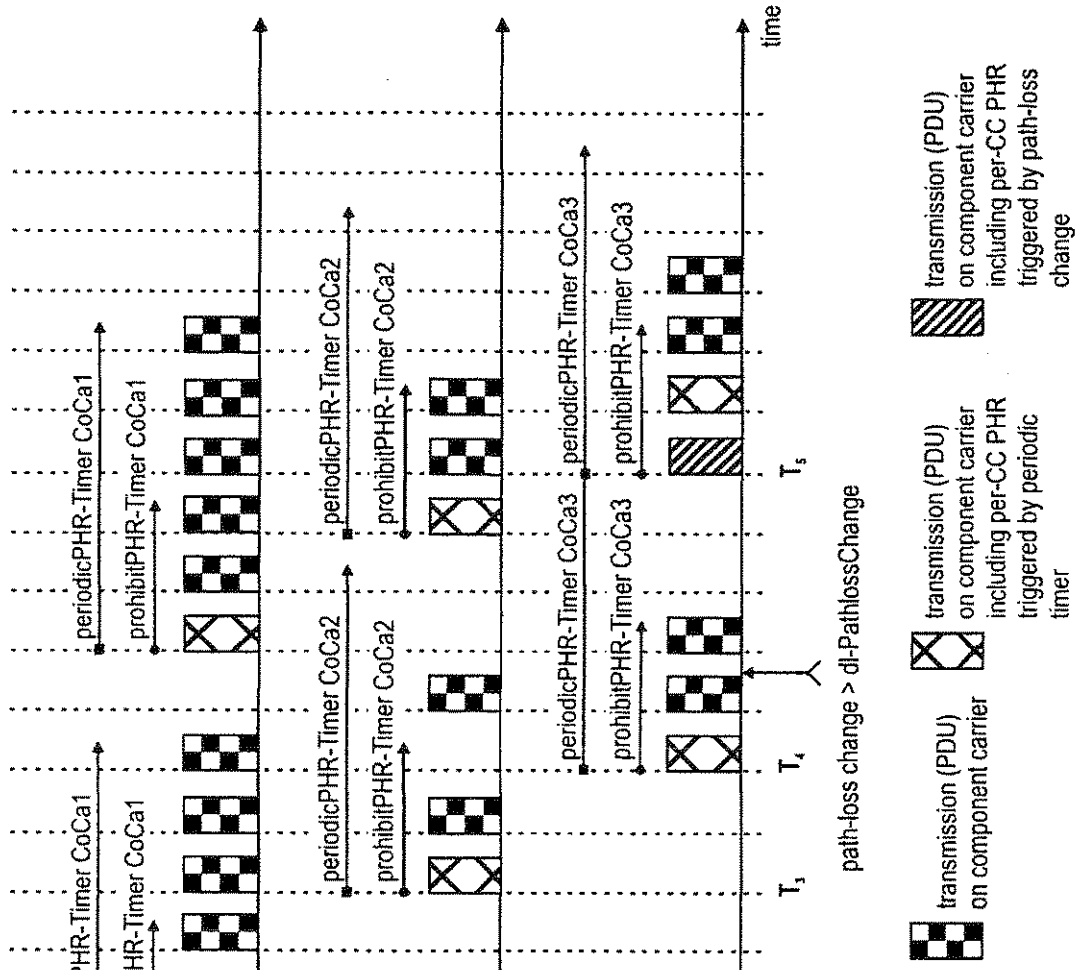

Uplink CoCa 1 (PUSCH/PUCCH)
Uplink CoCa 2 (PUSCH/PUCCH)
Uplink CoCa 3 (PUSCH/PUCCH)
periodicPHR-Timer CoCa1
prohibitPHR-Timer CoCa1
periodicPHR-Timer CoCa2
prohibitPHR-Timer CoCa2
periodicPHR-Timer CoCa3
prohibitPHR-Timer CoCa3
T1
sub-frame
T2
T3
T4
T5
time
path-loss change > dl-PathlossChange
transmission (PDU) on component carrier
transmission (PDU) on component carrier including per-CC PHR triggered by periodic timer
transmission (PDU) on component carrier including per-CC PHR triggered by path-loss change

Fig. 10

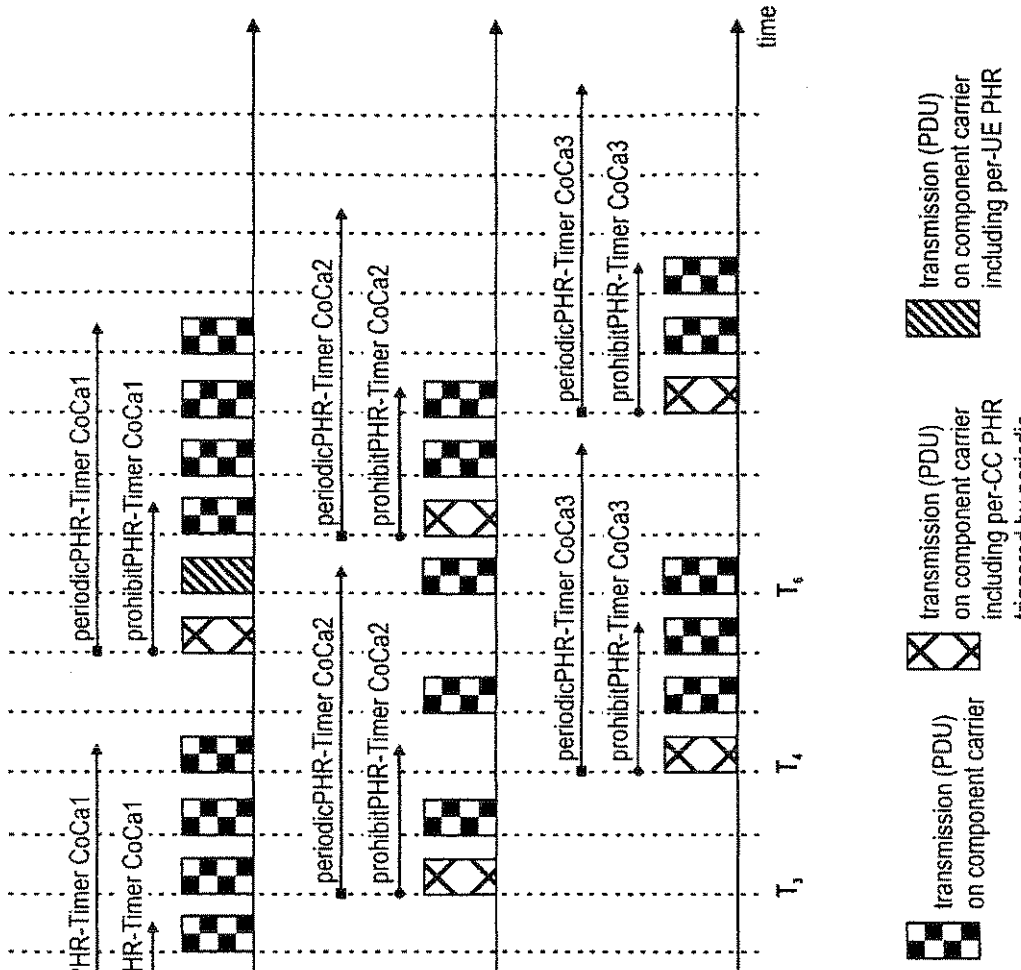

Uplink CoCa 1 (PUSCH/PUCCH)
Uplink CoCa 2 (PUSCH/PUCCH)
Uplink CoCa 3 (PUSCH/PUCCH)
periodicPHR-Timer CoCa1
prohibitPHR-Timer CoCa1
periodicPHR-Timer CoCa2
prohibitPHR-Timer CoCa2
periodicPHR-Timer CoCa3
prohibitPHR-Timer CoCa3
T1
T2
T3
T4
T5
sub-frame
time
transmission (PDU) on component carrier
transmission (PDU) on component carrier including per-CC PHR triggered by periodic timer
transmission (PDU) on component carrier including per-UE PHR

Fig. 11

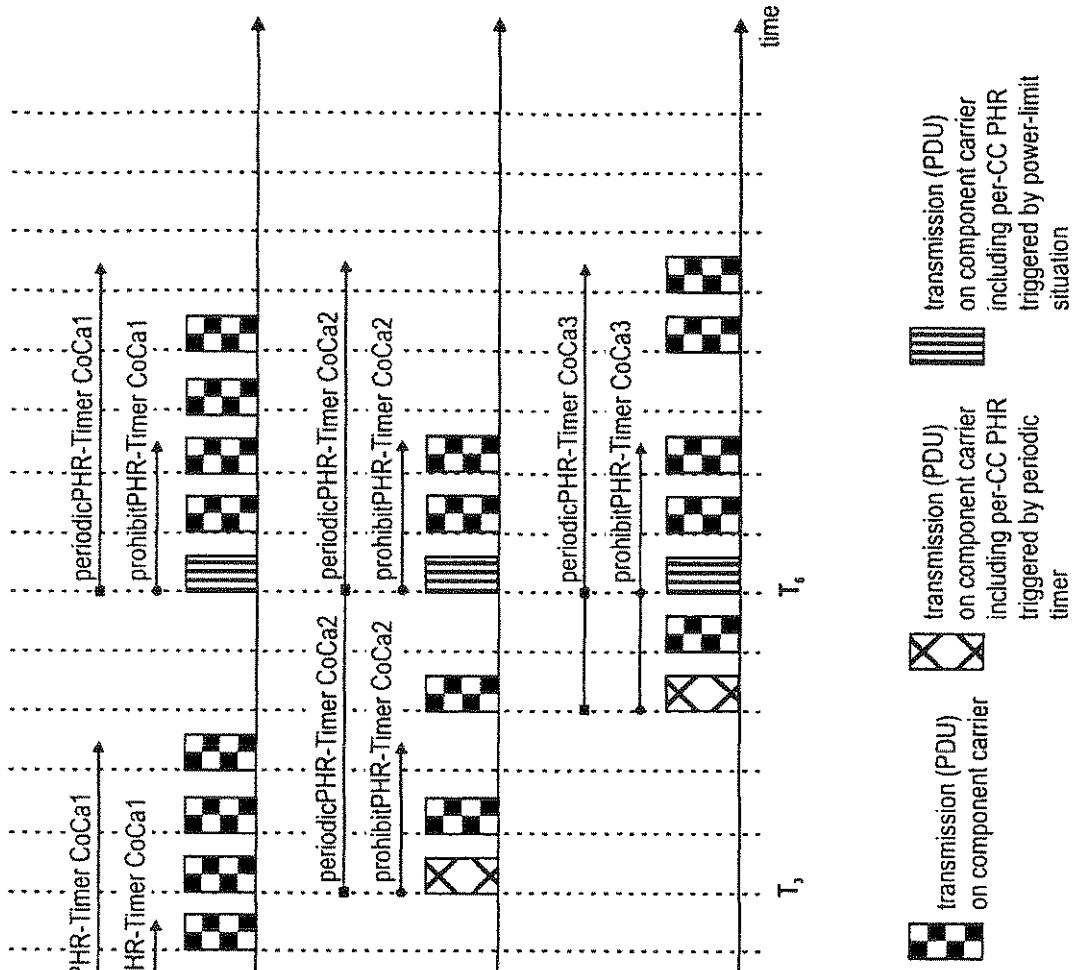

Uplink CoCa 1 (PUSCH/PUCCH)
Uplink CoCa 2 (PUSCH/PUCCH)
Uplink CoCa 3 (PUSCH/PUCCH)
periodicPHR-Timer CoCa1
prohibitPHR-Timer CoCa1
periodicPHR-Timer CoCa2
prohibitPHR-Timer CoCa2
periodicPHR-Timer CoCa3
prohibitPHR-Timer CoCa3
T1
T2
T3
T6
sub-frame
time
transmission (PDU) on component carrier
transmission (PDU) on component carrier including per-CC PHR triggered by periodic timer
transmission (PDU) on component carrier including per-CC PHR triggered by power-limit situation

Fig. 12

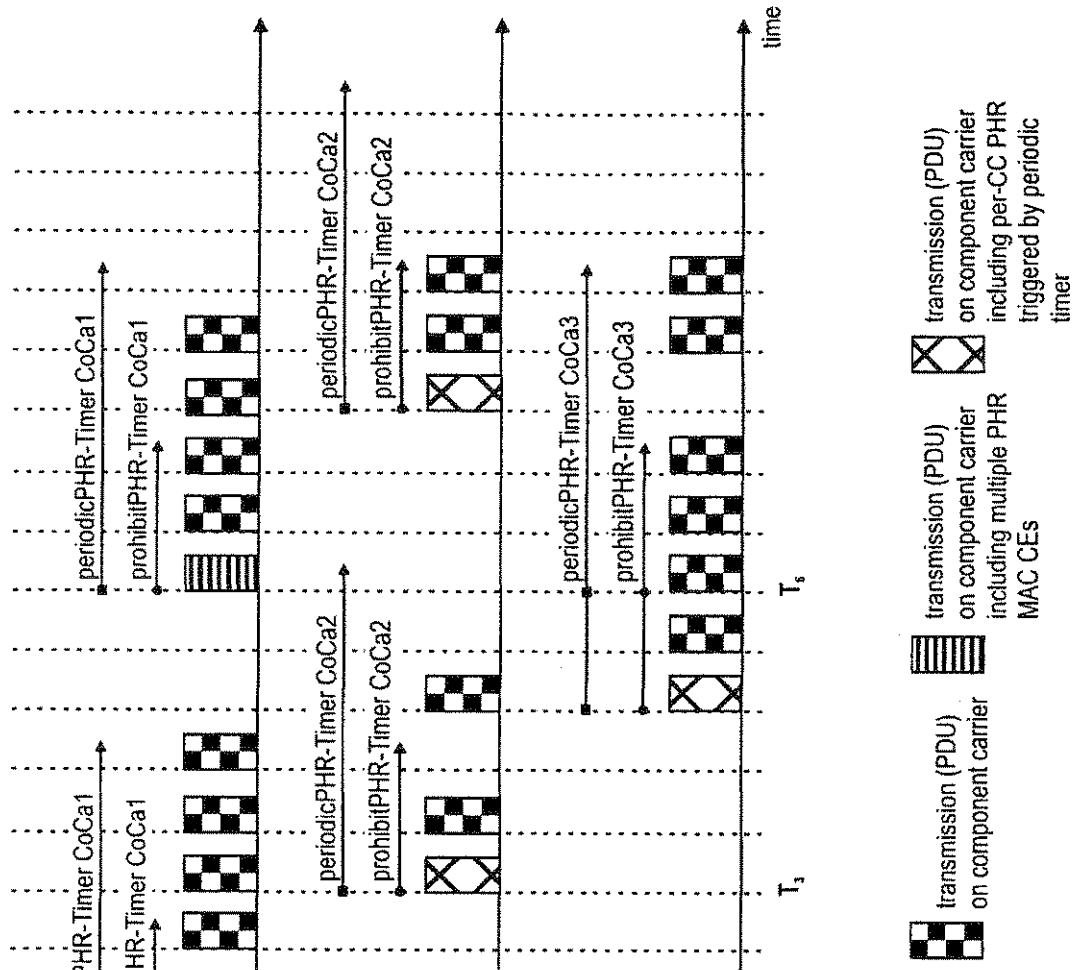

Uplink CoCa 1 (PUSCH/PUCCH)
Uplink CoCa 2 (PUSCH/PUCCH)
Uplink CoCa 3 (PUSCH/PUCCH)
periodicPHR-Timer CoCa1
prohibitPHR-Timer CoCa1
periodicPHR-Timer CoCa2
prohibitPHR-Timer CoCa2
periodicPHR-Timer CoCa3
prohibitPHR-Timer CoCa3
sub-frame
time
T1
T2
T3
T6
transmission (PDU) on component carrier
transmission (PDU) on component carrier including multiple PHR MAC CEs
transmission (PDU) on component carrier including per-CC PHR triggered by periodic timer

Fig. 13

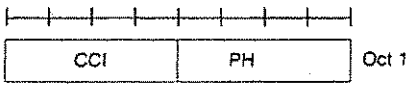


Fig. 14

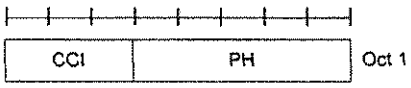


Fig. 15

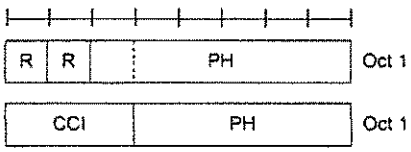


Fig. 16

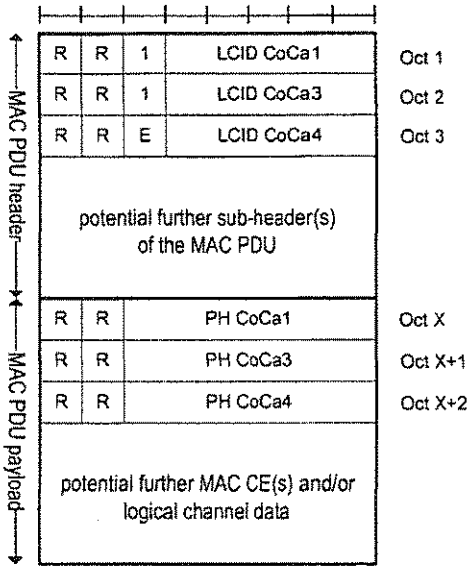

R
R
1
LCID CoCa1
Oct 1
R
R
1
LCID CoCa3
Oct 2
R
R
E
LCID CoCa4
Oct 3
potential further sub-header(s) of the MAC PDU
MAC PDU header
R
R
PH CoCa1
Oct X
R
R
PH CoCa3
Oct X+1
R
R
PH CoCa4
Oct X+2
potential further MAC CE(s) and/or logical channel data
MAC PDU payload

Fig. 17

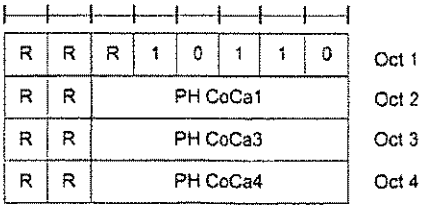

R
R
R
1
0
1
1
0
Oct 1
R
R
PH CoCa1
Oct 2
R
R
PH CoCa3
Oct 3
R
R
PH CoCa4
Oct 4

Fig. 18

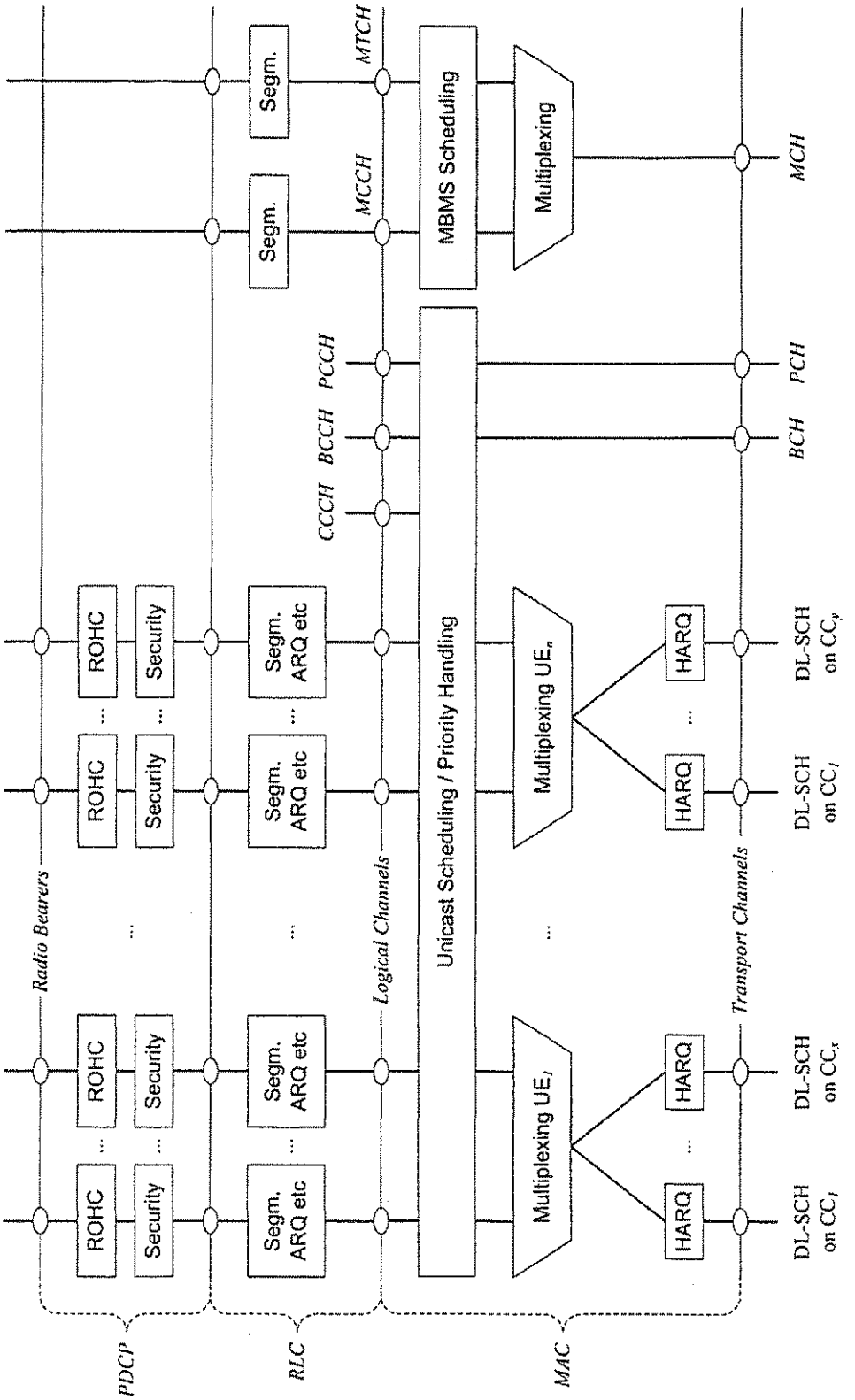

PDCP
RLC
MAC
Radio Bearers
Logical Channels
Transport Channels
ROHC
Security
Segm. ARQ etc
Segm.
HARQ
Unicast Scheduling / Priority Handling
MBMS Scheduling
Multiplexing
Multiplexing UE1
MultiplexingUEn
MTCH
MCCH
CCCH
BCCH
PCCH
MCH
BCH
PCH
DL-SCH on CC1
DL-SCH on CCx
DL-SCH on CCy

Fig. 19

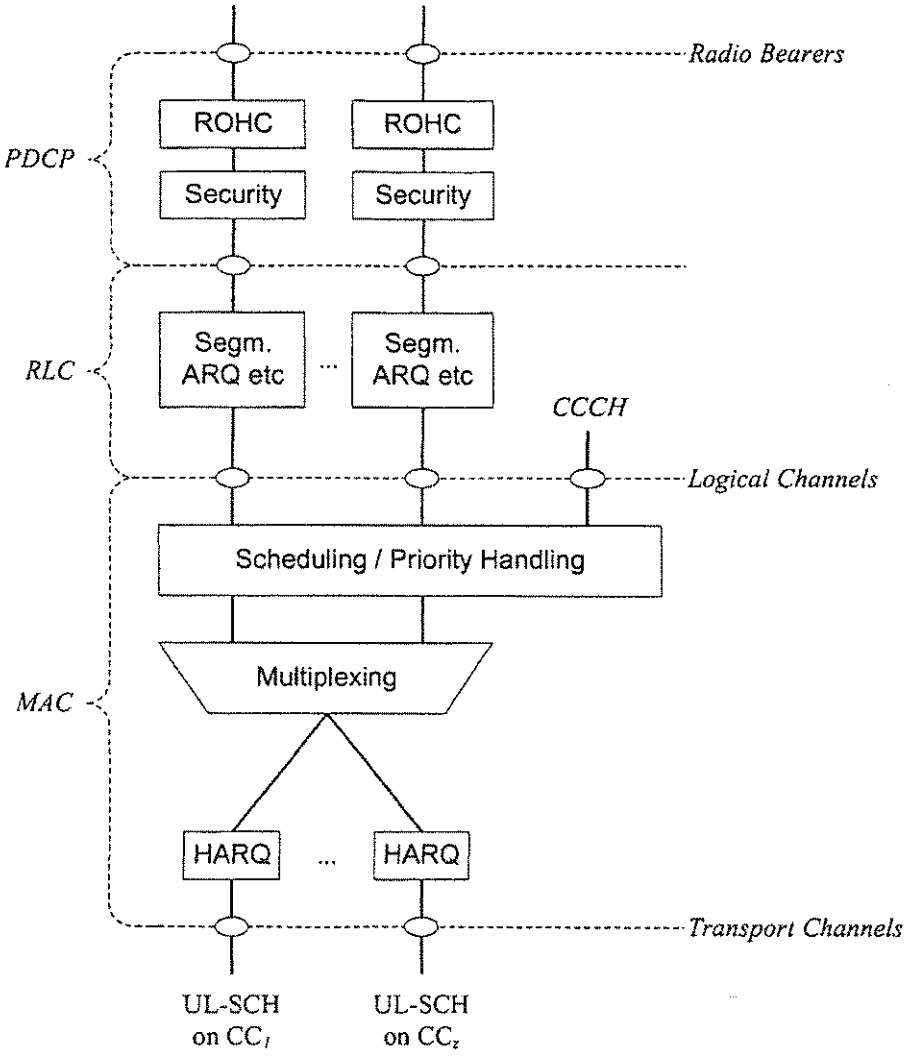

Radio Bearers
PDCP
ROHC
ROHC
Security
Security
RLC
Segm. ARQ etc
...
Segm. ARQ etc
CCCH
Logical Channels
Scheduling / Priority Handling
MAC
Multiplexing
HARQ
...
HARQ
Transport Channels
UL-SCH on CC1
UL-SCH on CCz

Fig. 20

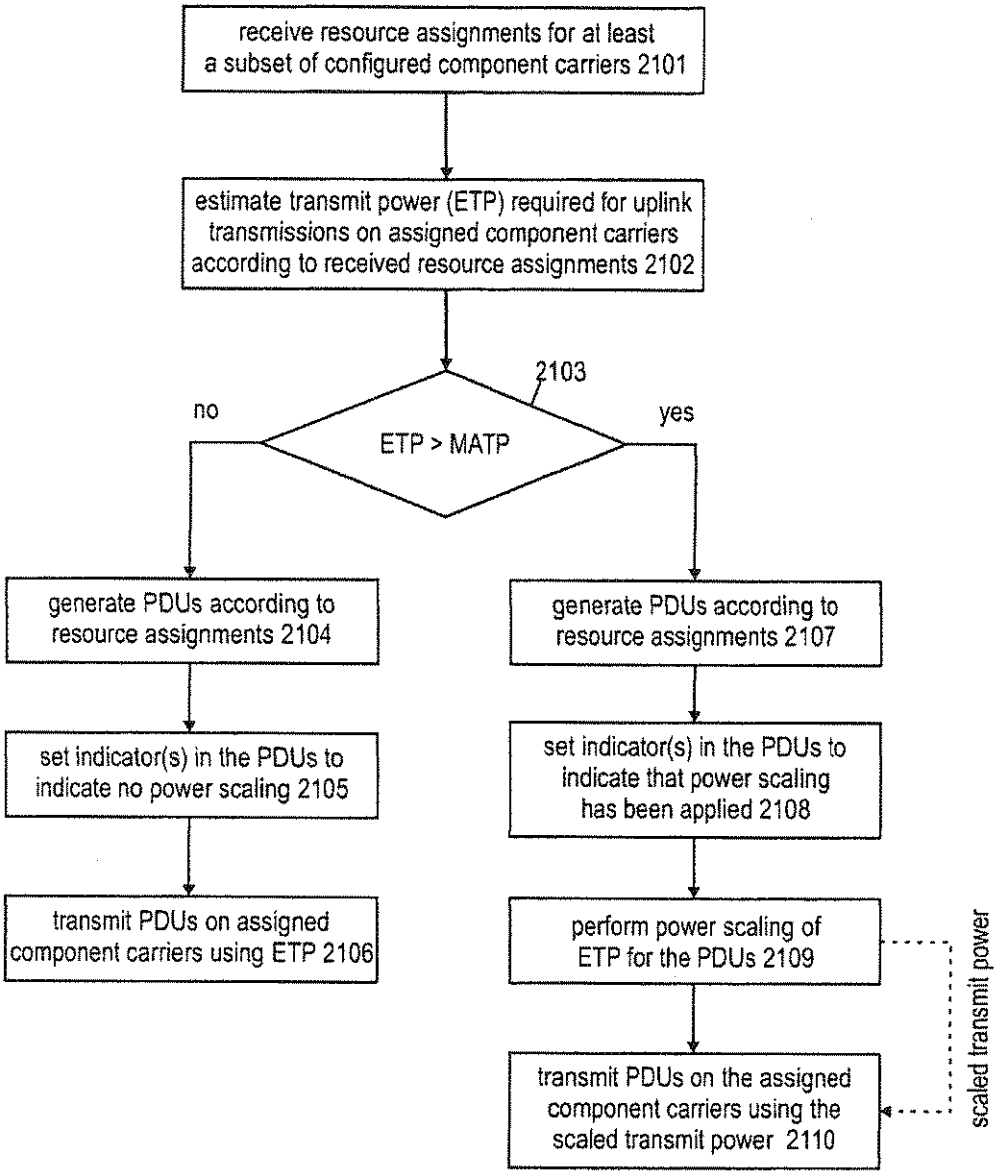

receive resource assignments for at least a subset of configured component carriers 2101
estimate transmit power (ETP) required for uplink transmissions on assigned component carriers according to received resource assignments 2102
2103
ETP > MATP
no
yes
generate PDUs according to resource assignments 2104
set indicator(s) in the PDUs to indicate no power scaling 2105
transmit PDUs on assigned component carriers using ETP 2106
generate PDUs according to resource assignments 2107
set indicator(s) in the PDUs to indicate that power scaling has been applied 2108
perform power scaling of ETP for the PDUs 2109
transmit PDUs on the assigned component carriers using the scaled transmit power 2110
scaled transmit power

Fig. 21

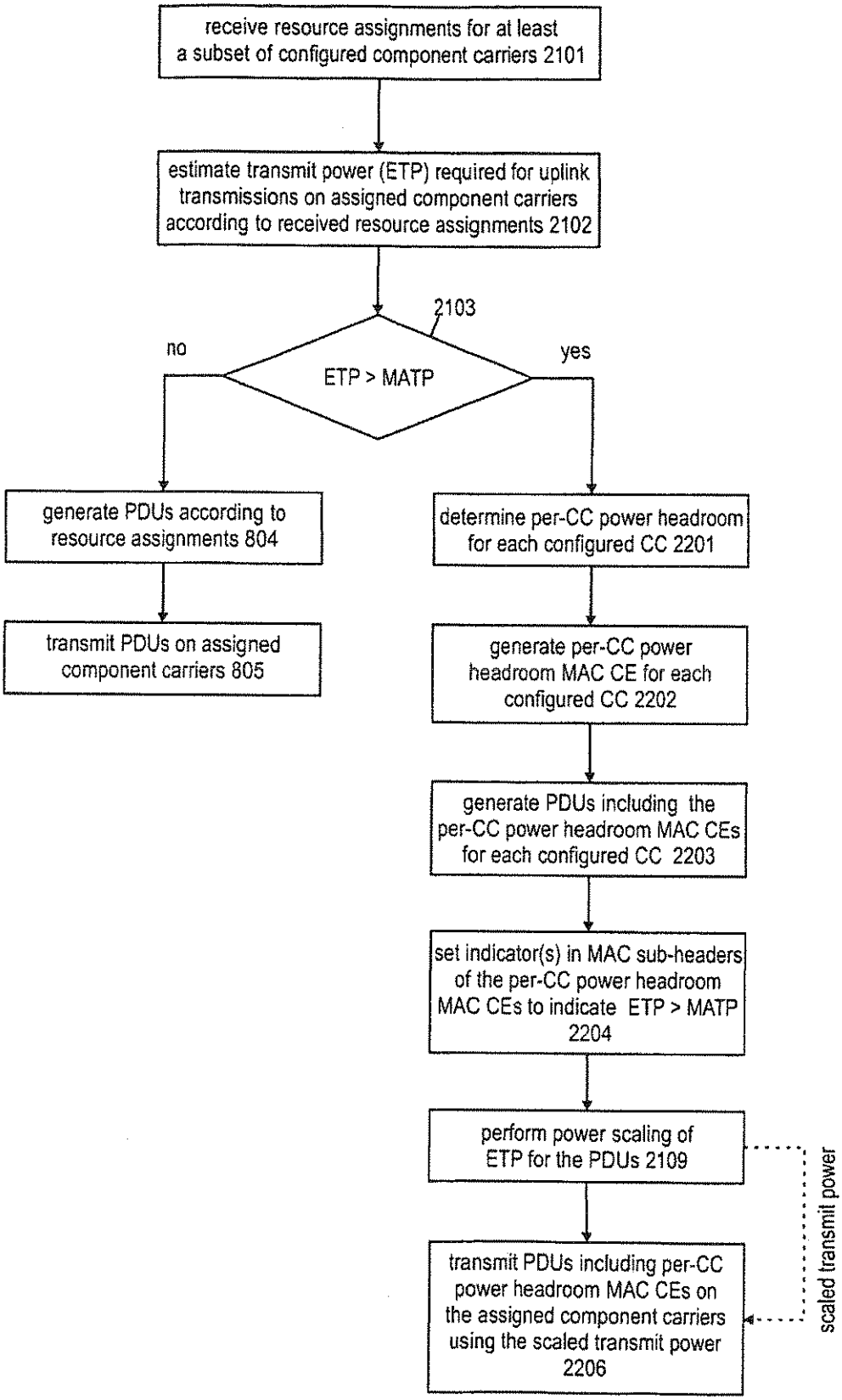

receive resource assignments for at least a subset of configured component carriers 2101
estimate transmit power (ETP) required for uplink transmissions on assigned component carriers according to received resource assignments 2102
2103
ETP > MATP
no
yes
generate PDUs according to resource assignments 804
transmit PDUs on assigned component carriers 805
determine per-CC power headroom for each configured CC 2201
generate per-CC power headroom MAC CE for each configured CC 2202
generate PDUs including the per-CC power headroom MAC CEs for each configured CC 2203
set indicator(s) in MAC sub-headers of the per-CC power headroom MAC CEs to indicate ETP > MATP 2204
perform power scaling of ETP for the PDUs 2109
transmit PDUs including per-CC power headroom MAC CEs on the assigned component carriers using the scaled transmit power 2206
scaled transmit power

Fig. 22

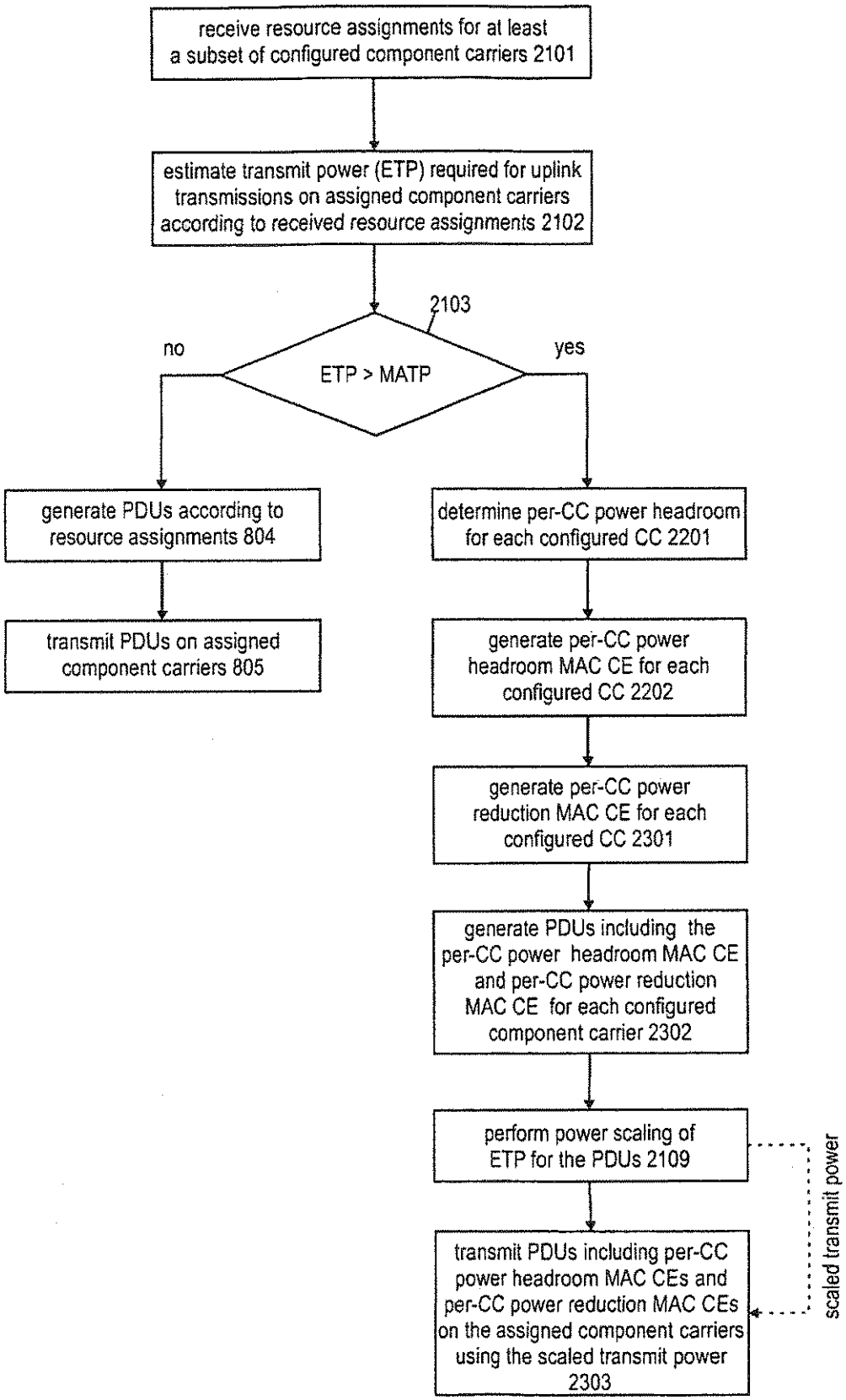

receive resource assignments for at least a subset of configured component carriers 2101
estimate transmit power (ETP) required for uplink transmissions on assigned component carriers according to received resource assignments 2102
2103
ETP > MATP
no
yes
generate PDUs according to resource assignments 804
transmit PDUs on assigned component carriers 805
determine per-CC power headroom for each configured CC 2201
generate per-CC power headroom MAC CE for each configured CC 2202
generate per-CC power reduction MAC CE for each configured CC 2301
generate PDUs including the per-CC power headroom MAC CE and per-CC power reduction MAC CE for each configured component carrier 2302
perform power scaling of ETP for the PDUs 2109
transmit PDUs including per-CC power headroom MAC CEs and per-CC power reduction MAC CEs on the assigned component carriers using the scaled transmit power 2303
scaled transmit power

Fig. 23

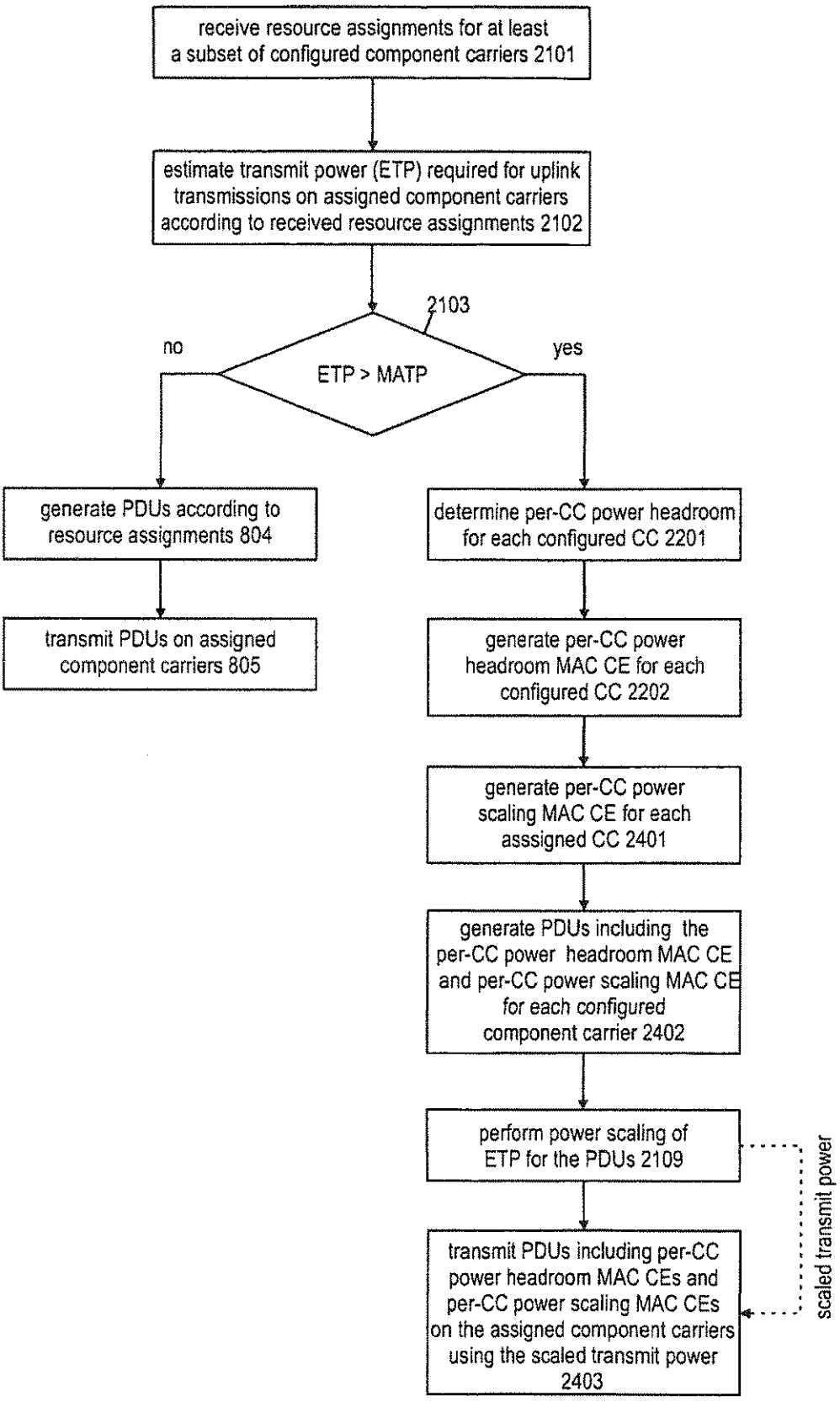

receive resource assignments for at least a subset of configured component carriers 2101
estimate transmit power (ETP) required for uplink transmissions on assigned component carriers according to received resource assignments 2102
2103
ETP > MATP
no
yes
generate PDUs according to resource assignments 804
transmit PDUs on assigned component carriers 805
determine per-CC power headroom for each configured CC 2201
generate per-CC power headroom MAC CE for each configured CC 2202
generate per-CC power scaling MAC CE for each asssigned CC 2401
generate PDUs including the per-CC power headroom MAC CE and per-CC power scaling MAC CE for each configured component carrier 2402
perform power scaling of ETP for the PDUs 2109
transmit PDUs including per-CC power headroom MAC CEs and per-CC power scaling MAC CEs on the assigned component carriers using the scaled transmit power 2403
scaled transmit power

Fig. 24

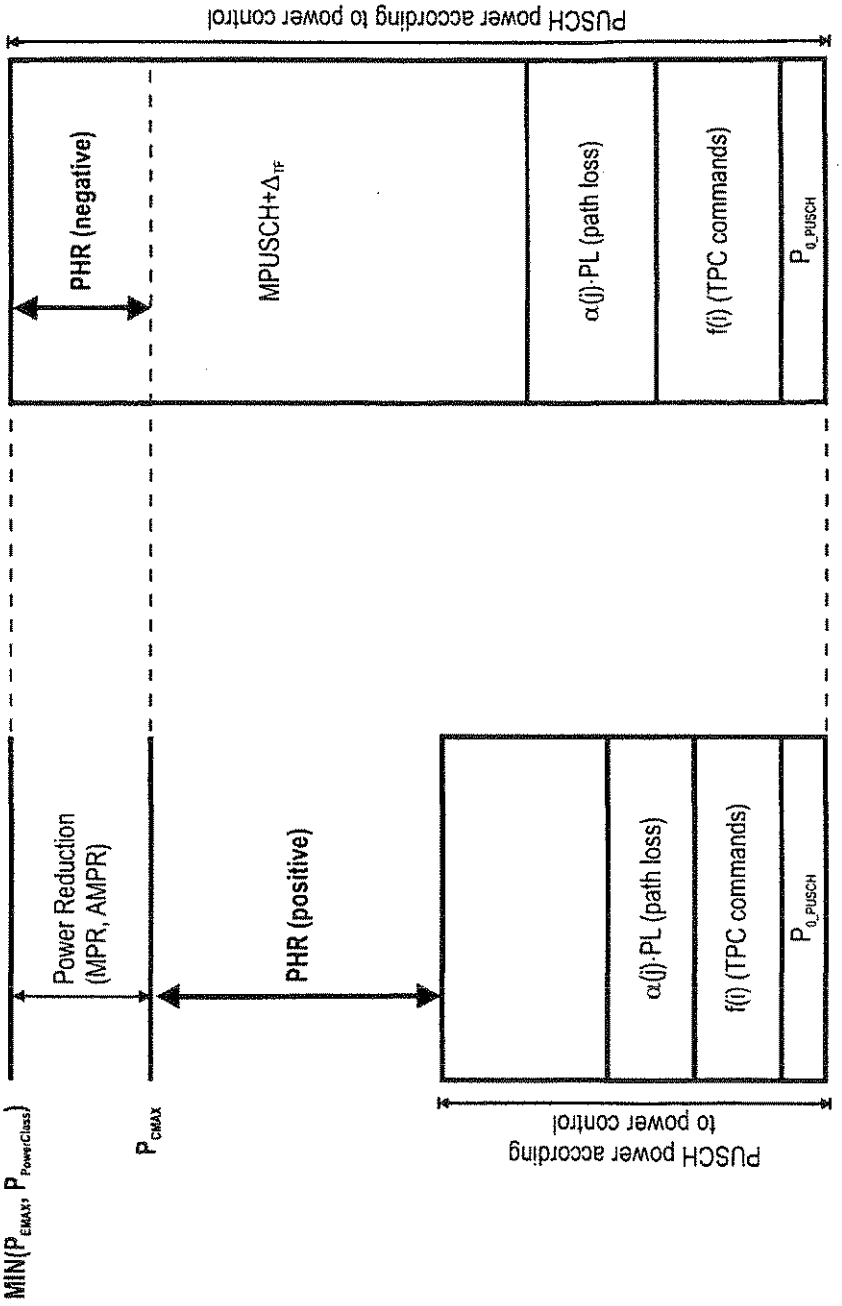

PUSCH power according to power control
PHR (negative)
MPUSCH+Δ_TF
α(j)·PL (path loss)
f(i) (TPC commands)
P_0_PUSCH
Power Reduction (MPR, AMPR)
PHR (positive)
α(j)·PL (path loss)
f(i) (TPC commands)
P_0_PUSCH
PUSCH power according to power control
P_CMAX
MIN(P_EMAX, P_PowerClass)

Fig. 25

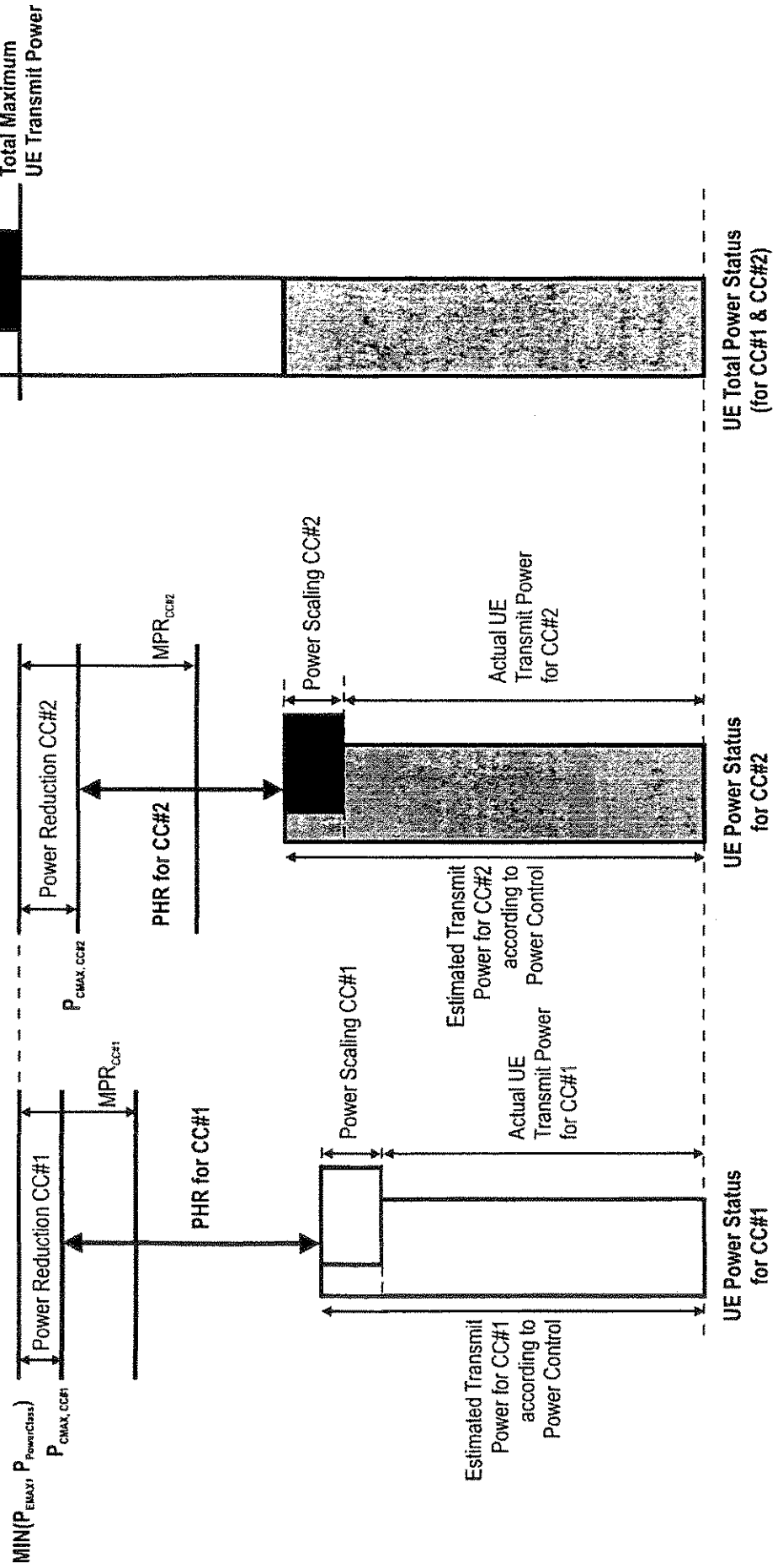

Total Maximum UE Transmit Power
UE Total Power Status (for CC#1 & CC#2)
Power Scaling CC#2
Actual UE Transmit Power for CC#2
UE Power Status for CC#2
Estimated Transmit Power for CC#2 according to Power Control
MPR CC#2
Power Reduction CC#2
PHR for CC#2
P CMAX, CC#2
Power Scaling CC#1
Actual UE Transmit Power for CC#1
UE Power Status for CC#1
Estimated Transmit Power for CC#1 according to Power Control
MPR CC#1
Power Reduction CC#1
PHR for CC#1
MIN(P EMAX1 P PowerClass)
P CMAX, CC#1

Fig. 26

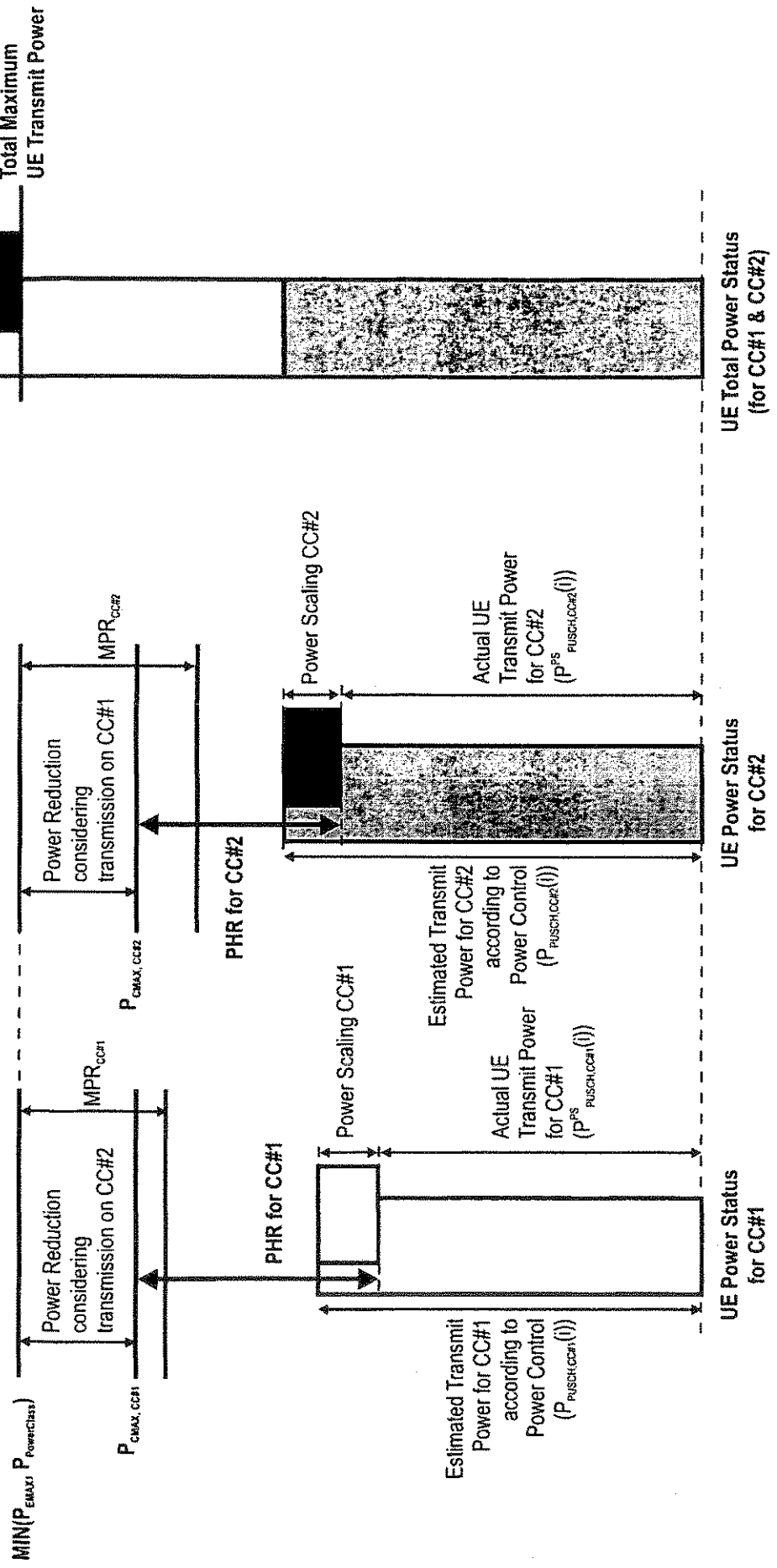

Total Maximum UE Transmit Power
UE Total Power Status (for CC#1 & CC#2)
Power Reduction considering transmission on CC#1
MPR CC#2
P CMAX, CC#2
PHR for CC#2
Power Scaling CC#2
Actual UE Transmit Power for CC#2 (P PS PUSCH,CC#2(i))
Estimated Transmit Power for CC#2 according to Power Control (P PUSCH,CC#2(i))
UE Power Status for CC#2
Power Reduction considering transmission on CC#2
MPR CC#1
P CMAX, CC#1
PHR for CC#1
Power Scaling CC#1
Actual UE Transmit Power for CC#1 (P PS PUSCH,CC#1(i))
Estimated Transmit Power for CC#1 according to Power Control (P PUSCH,CC#1(i))
UE Power Status for CC#1
MIN(P EMAX1 P PowerClass)

Fig. 27

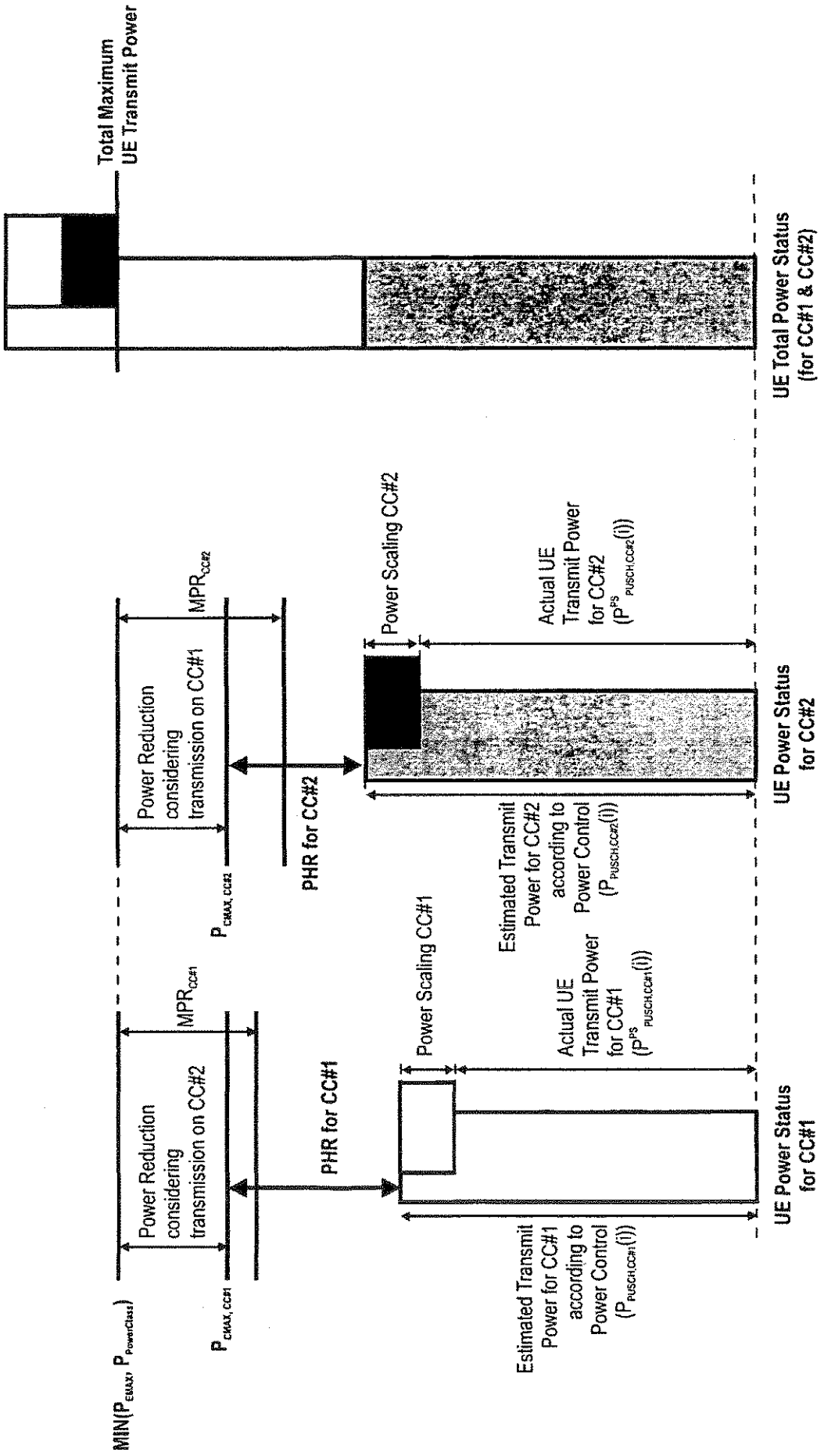

Total Maximum UE Transmit Power
UE Total Power Status (for CC#1 & CC#2)
Power Scaling CC#2
Actual UE Transmit Power for CC#2 ($P^{PS}_{PUSCH,CC\#2}(i)$)
$MPR_{CC\#2}$
Power Reduction considering transmission on CC#1
$P_{CMAX,CC\#2}$
PHR for CC#2
UE Power Status for CC#2
Estimated Transmit Power for CC#2 according to Power Control ($P_{PUSCH,CC\#2}(i)$)
Power Scaling CC#1
Actual UE Transmit Power for CC#1 ($P^{PS}_{PUSCH,CC\#1}(i)$)
$MPR_{CC\#1}$
Power Reduction considering transmission on CC#2
PHR for CC#1
UE Power Status for CC#1
Estimated Transmit Power for CC#1 according to Power Control ($P_{PUSCH,CC\#1}(i)$)
$P_{CMAX,CC\#1}$
$MIN(P_{EMAX}, P_{PowerClass})$

Fig. 28

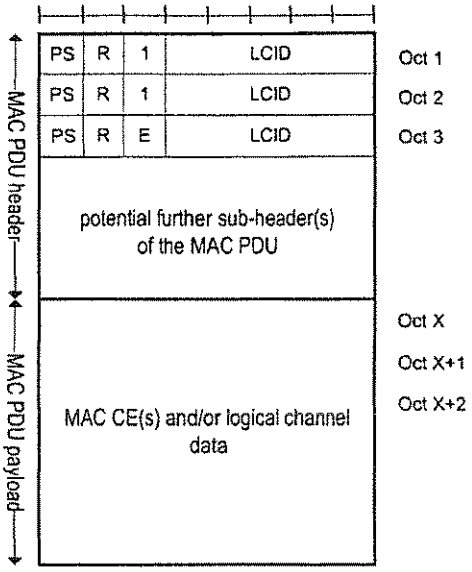

PS
R
1
LCID
Oct 1
PS
R
1
LCID
Oct 2
PS
R
E
LCID
Oct 3
potential further sub-header(s) of the MAC PDU
MAC PDU header
MAC CE(s) and/or logical channel data
MAC PDU payload
Oct X
Oct X+1
Oct X+2

Fig. 29

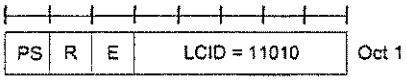

PS
R
E
LCID = 11010
Oct 1

Fig. 30

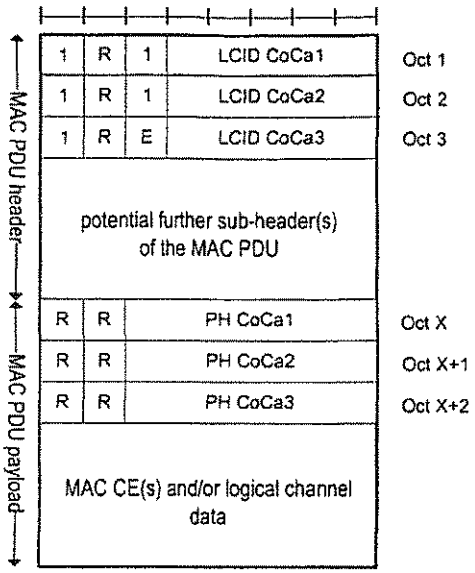


Fig. 31

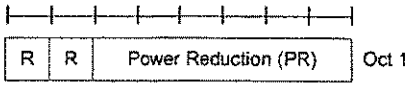


Fig. 32

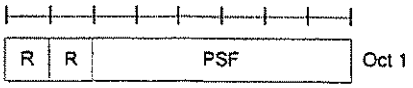


Fig. 33