Fig. 1

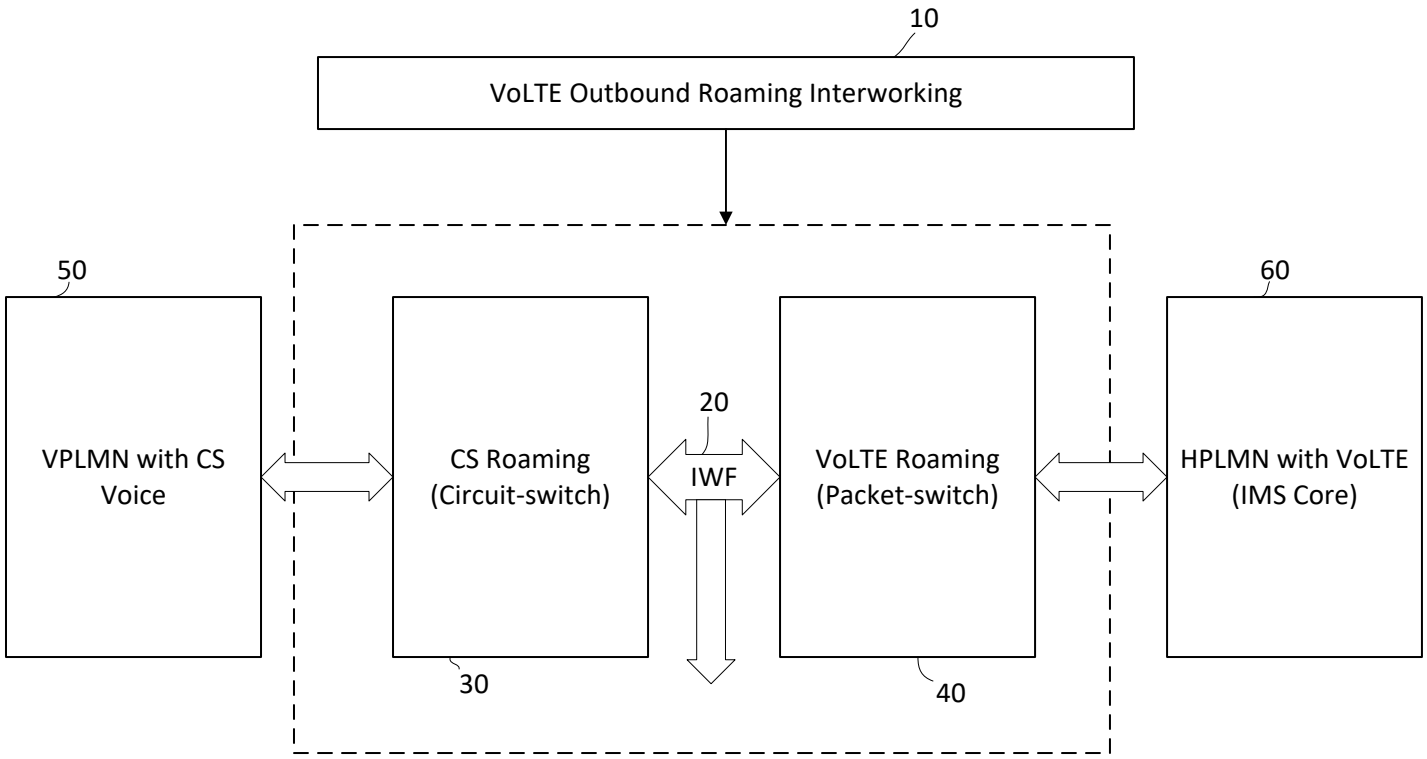

10
VoLTE Outbound Roaming Interworking
50
VPLMN with CS Voice
CS Roaming (Circuit-switch)
20
IWF
VoLTE Roaming (Packet-switch)
60
HPLMN with VoLTE (IMS Core)
30
40

Fig. 2

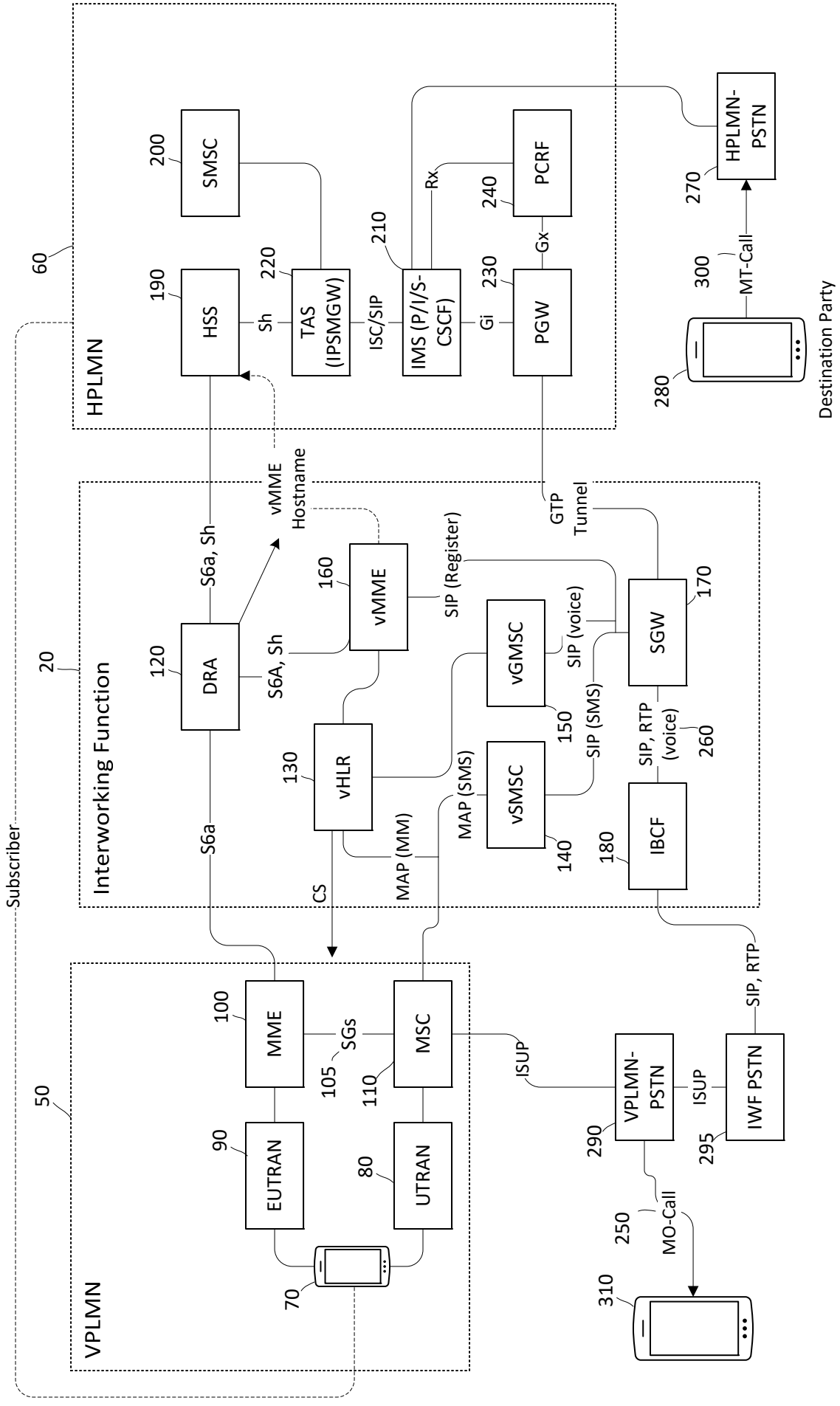

Subscriber
HPLMN
60
SMSC
200
HSS
190
Sh
TAS (IPSMGW)
220
ISC/SIP
IMS (P/I/S-CSCF)
210
Rx
PCRF
240
Gi
PGW
230
Gx
HPLMN-PSTN
270
300
MT-Call
280
Destination Party
Interworking Function
20
vMME Hostname
S6a, Sh
DRA
120
S6A, Sh
vMME
160
SIP (Register)
GTP Tunnel
vGMSC
150
SIP (voice)
SGW
170
SIP (SMS)
SIP, RTP (voice)
260
vHLR
130
MAP (SMS)
vSMSC
140
IBCF
180
S6a
MAP (MM)
CS
VPLMN
50
MME
100
SGs
105
MSC
110
ISUP
SIP, RTP
EUTRAN
90
UTRAN
80
VPLMN-PSTN
290
ISUP
IWF PSTN
295
70
MO-Call
250
310

Fig. 3

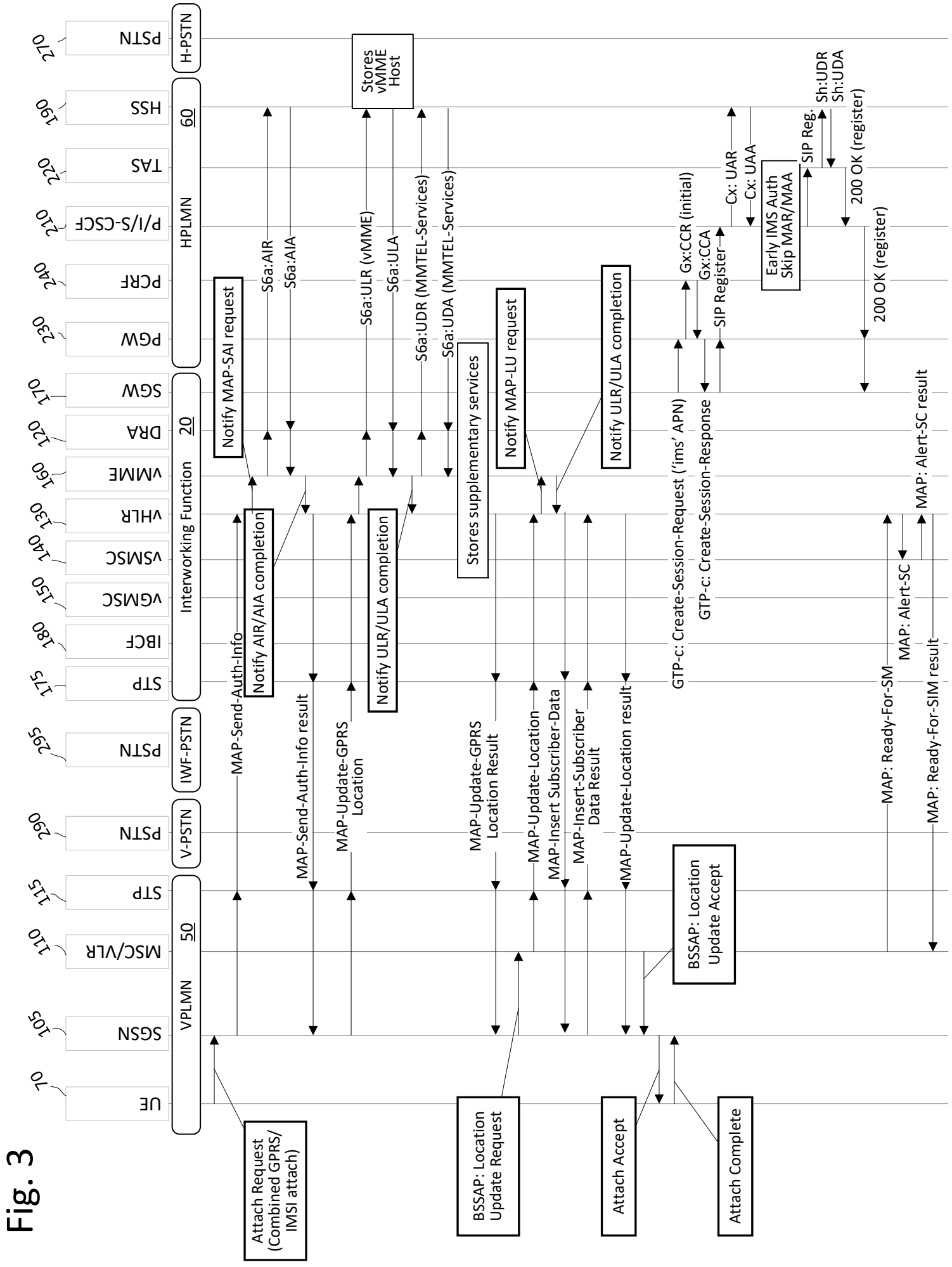

UE
70
VPLMN
SGSN
105
MSC/VLR
110
STP
115
V-PSTN
PSTN
290
IWF-PSTN
PSTN
295
50
Interworking Function
STP
175
IBCF
180
vGMSC
150
vSMSC
140
vHLR
130
vMME
160
DRA
120
SGW
170
20
HPLMN
PGW
230
PCRF
240
P/I/S-CSCF
210
TAS
220
HSS
190
60
H-PSTN
PSTN
270
Attach Request (Combined GPRS/ IMSI attach)
MAP-Send-Auth-Info
Notify AIR/AIA completion
S6a:AIR
S6a:AIA
Notify MAP-SAI request
Stores vMME Host
MAP-Send-Auth-Info result
MAP-Update-GPRS Location
Notify ULR/ULA completion
S6a:ULR (vMME)
S6a:ULA
S6a:UDR (MMTEL-Services)
S6a:UDA (MMTEL-Services)
Stores supplementary services
Notify MAP-LU request
Notify ULR/ULA completion
MAP-Update-GPRS Location Result
MAP-Update-Location
MAP-Insert Subscriber-Data
MAP-Insert-Subscriber Data Result
MAP-Update-Location result
BSSAP: Location Update Request
BSSAP: Location Update Accept
Attach Accept
Attach Complete
GTP-c: Create-Session-Request (‘ims’ APN)
GTP-c: Create-Session-Response
Gx:CCR (initial)
Gx:CCA
SIP Register
Cx: UAR
Cx: UAA
Early IMS Auth Skip MAR/MAA
SIP Reg.
Sh:UDR
Sh:UDA
200 OK (register)
200 OK (register)
MAP: Ready-For-SM
MAP: Alert-SC
MAP: Alert-SC result
MAP: Ready-For-SIM result

Fig. 4

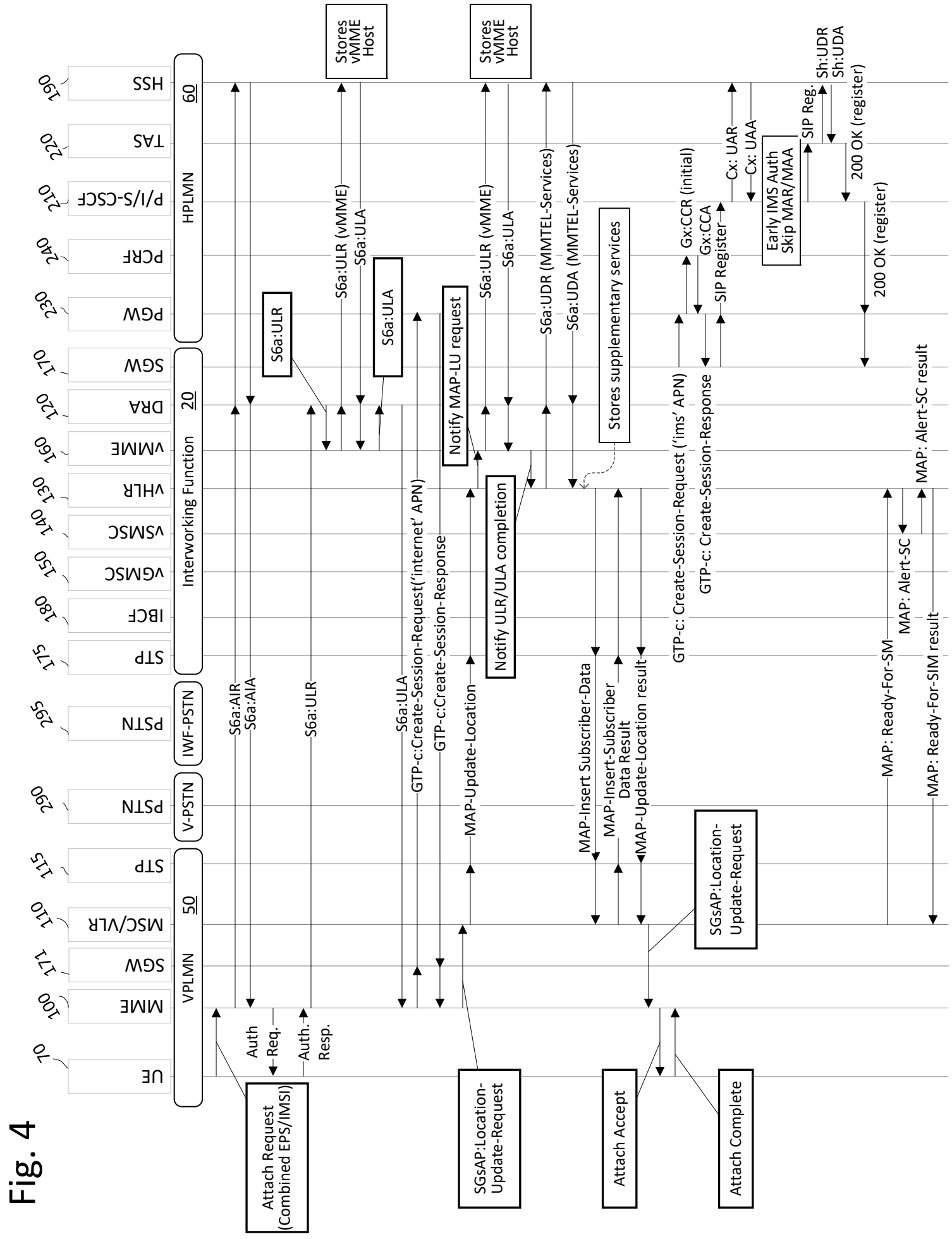

UE
MME
SGW
MSC/VLR
STP
PSTN
STP
IBCF
vGMSC
vSMSC
vHLR
vMME
DRA
SGW
PGW
PCRF
P/I/S-CSCF
TAS
HSS
VPLMN 50
V-PSTN
IWF-PSTN
Interworking Function 20
HPLMN 60
Attach Request (Combined EPS/IMSI)
Auth Req.
Auth. Resp.
S6a:AIR
S6a:AIA
S6a:ULR
S6a:ULR
S6a:ULA
GTP-c:Create-Session-Request('internet' APN)
GTP-c:Create-Session-Response
MAP-Update-Location
Notify MAP-LU request
Notify ULR/ULA completion
S6a:ULR (vMME)
S6a:ULA
Stores vMME Host
S6a:ULR (vMME)
S6a:ULA
Stores vMME Host
S6a:UDR (MMTEL-Services)
S6a:UDA (MMTEL-Services)
Stores supplementary services
MAP-Insert Subscriber-Data
MAP-Insert-Subscriber Data Result
MAP-Update-Location result
SGsAP:Location-Update-Request
SGsAP:Location-Update-Request
Attach Accept
Attach Complete
GTP-c: Create-Session-Request ('ims' APN)
GTP-c: Create-Session-Response
Gx:CCR (initial)
Gx:CCA
SIP Register
Cx: UAR
Cx: UAA
Early IMS Auth Skip MAR/MAA
SIP Reg.
Sh:UDR
Sh:UDA
200 OK (register)
200 OK (register)
MAP: Ready-For-SM
MAP: Alert-SC
MAP: Alert-SC result
MAP: Ready-For-SIM result

Fig. 5

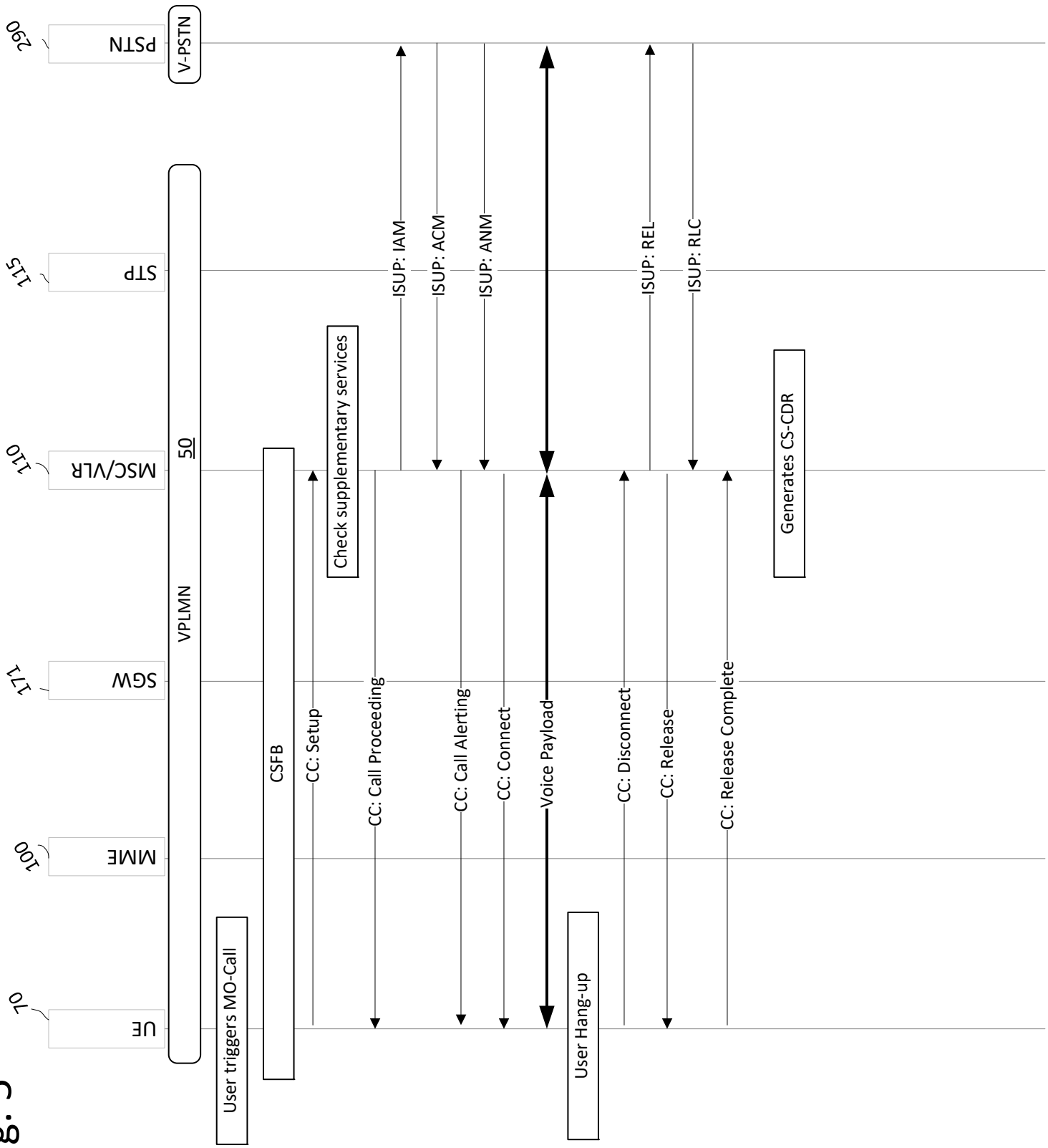

UE
70
MME
100
SGW
171
VPLMN
50
MSC/VLR
110
STP
115
V-PSTN
PSTN
290
User triggers MO-Call
CSFB
CC: Setup
Check supplementary services
CC: Call Proceeding
ISUP: IAM
CC: Call Alerting
ISUP: ACM
CC: Connect
ISUP: ANM
Voice Payload
User Hang-up
CC: Disconnect
ISUP: REL
CC: Release
ISUP: RLC
CC: Release Complete
Generates CS-CDR

Fig. 6A

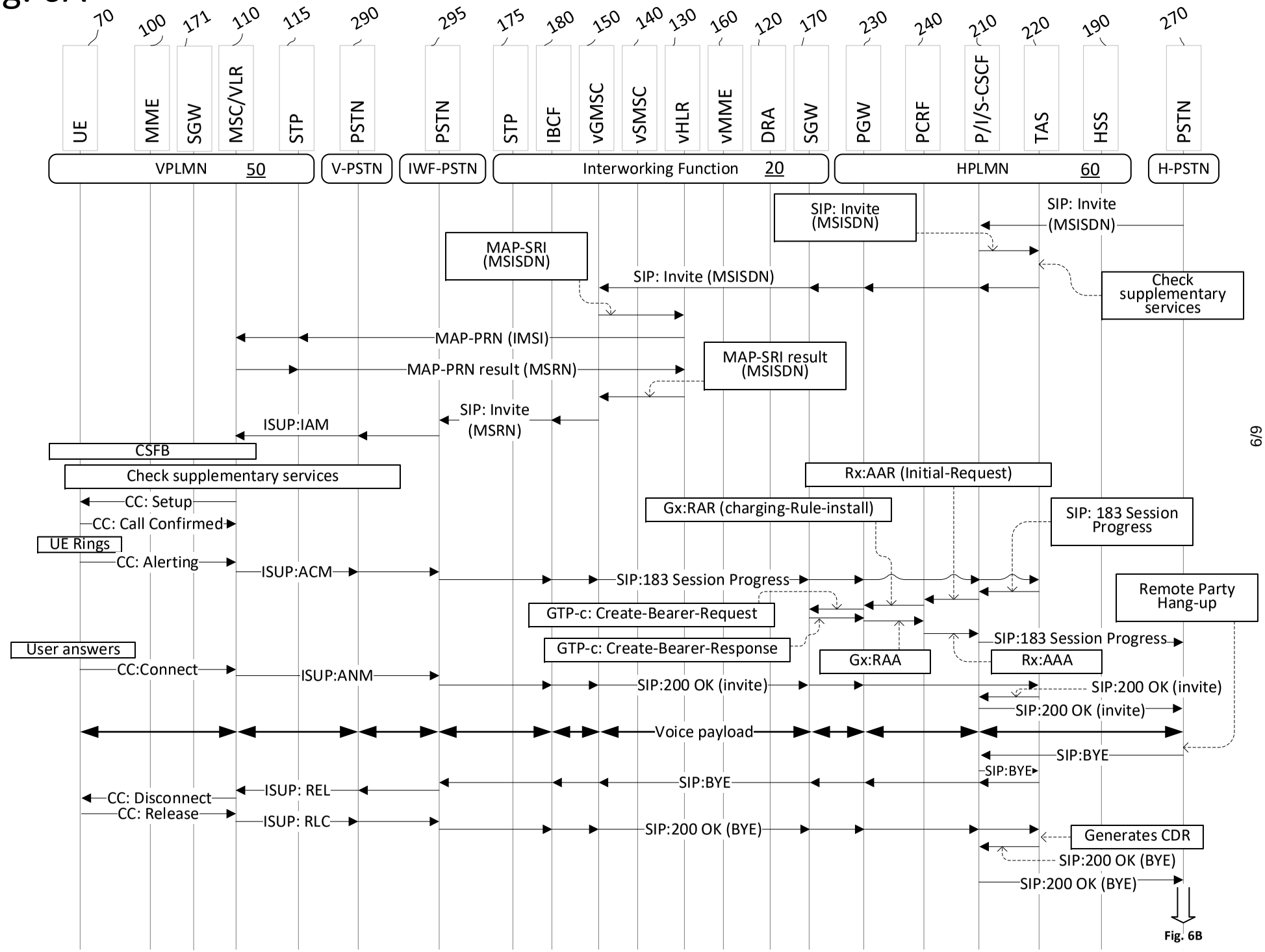

70
100
171
110
115
290
295
175
180
150
140
130
160
120
170
230
240
210
220
190
270
UE
MME
SGW
MSC/VLR
STP
PSTN
PSTN
STP
IBCF
vGMSC
vSMSC
vHLR
vMME
DRA
SGW
PGW
PCRF
P/I/S-CSCF
TAS
HSS
PSTN
VPLMN 50
V-PSTN
IWF-PSTN
Interworking Function 20
HPLMN 60
H-PSTN
SIP: Invite (MSISDN)
SIP: Invite (MSISDN)
MAP-SRI (MSISDN)
SIP: Invite (MSISDN)
Check supplementary services
MAP-PRN (IMSI)
MAP-SRI result (MSISDN)
MAP-PRN result (MSRN)
SIP: Invite (MSRN)
ISUP:IAM
CSFB
Check supplementary services
Rx:AAR (Initial-Request)
CC: Setup
Gx:RAR (charging-Rule-install)
SIP: 183 Session Progress
CC: Call Confirmed
UE Rings
CC: Alerting
ISUP:ACM
SIP:183 Session Progress
Remote Party Hang-up
GTP-c: Create-Bearer-Request
SIP:183 Session Progress
User answers
GTP-c: Create-Bearer-Response
Gx:RAA
Rx:AAA
CC:Connect
ISUP:ANM
SIP:200 OK (invite)
SIP:200 OK (invite)
SIP:200 OK (invite)
Voice payload
SIP:BYE
SIP:BYE
ISUP: REL
SIP:BYE
CC: Disconnect
CC: Release
ISUP: RLC
SIP:200 OK (BYE)
Generates CDR
SIP:200 OK (BYE)
SIP:200 OK (BYE)
Fig. 6B

Fig. 6B

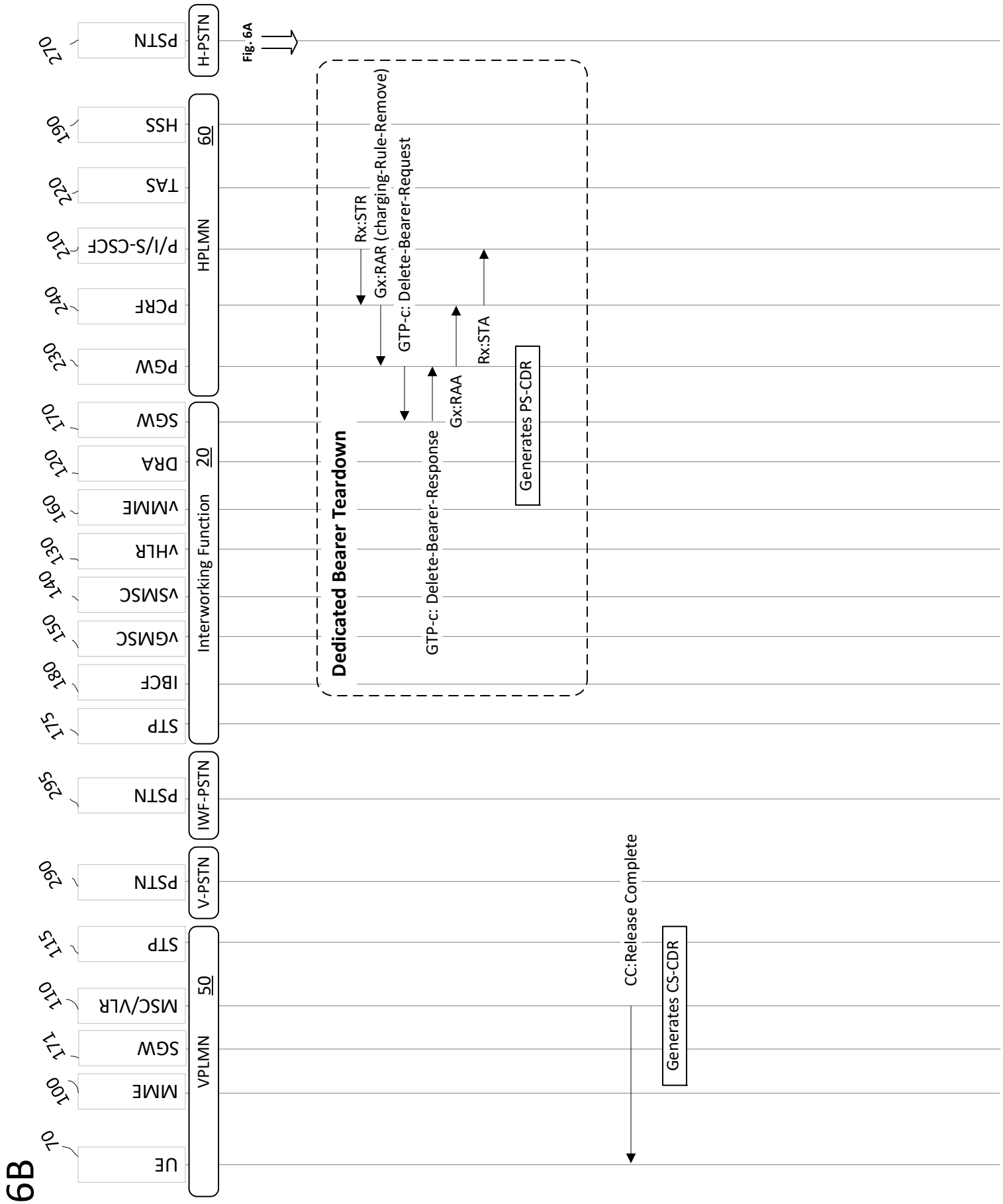

UE
70
VPLMN
50
MME
100
SGW
171
MSC/VLR
110
STP
115
V-PSTN
PSTN
290
IWF-PSTN
PSTN
295
Interworking Function
20
STP
175
IBCF
180
vGMSC
150
vSMSC
140
vHLR
130
vMME
160
DRA
120
SGW
170
HPLMN
60
PGW
230
PCRF
240
P/I/S-CSCF
210
TAS
220
HSS
190
H-PSTN
PSTN
270
Fig. 6A
Dedicated Bearer Teardown
Rx:STR
Gx:RAR (charging-Rule-Remove)
GTP-c: Delete-Bearer-Request
GTP-c: Delete-Bearer-Response
Gx:RAA
Rx:STA
Generates PS-CDR
CC:Release Complete
Generates CS-CDR

Fig. 7

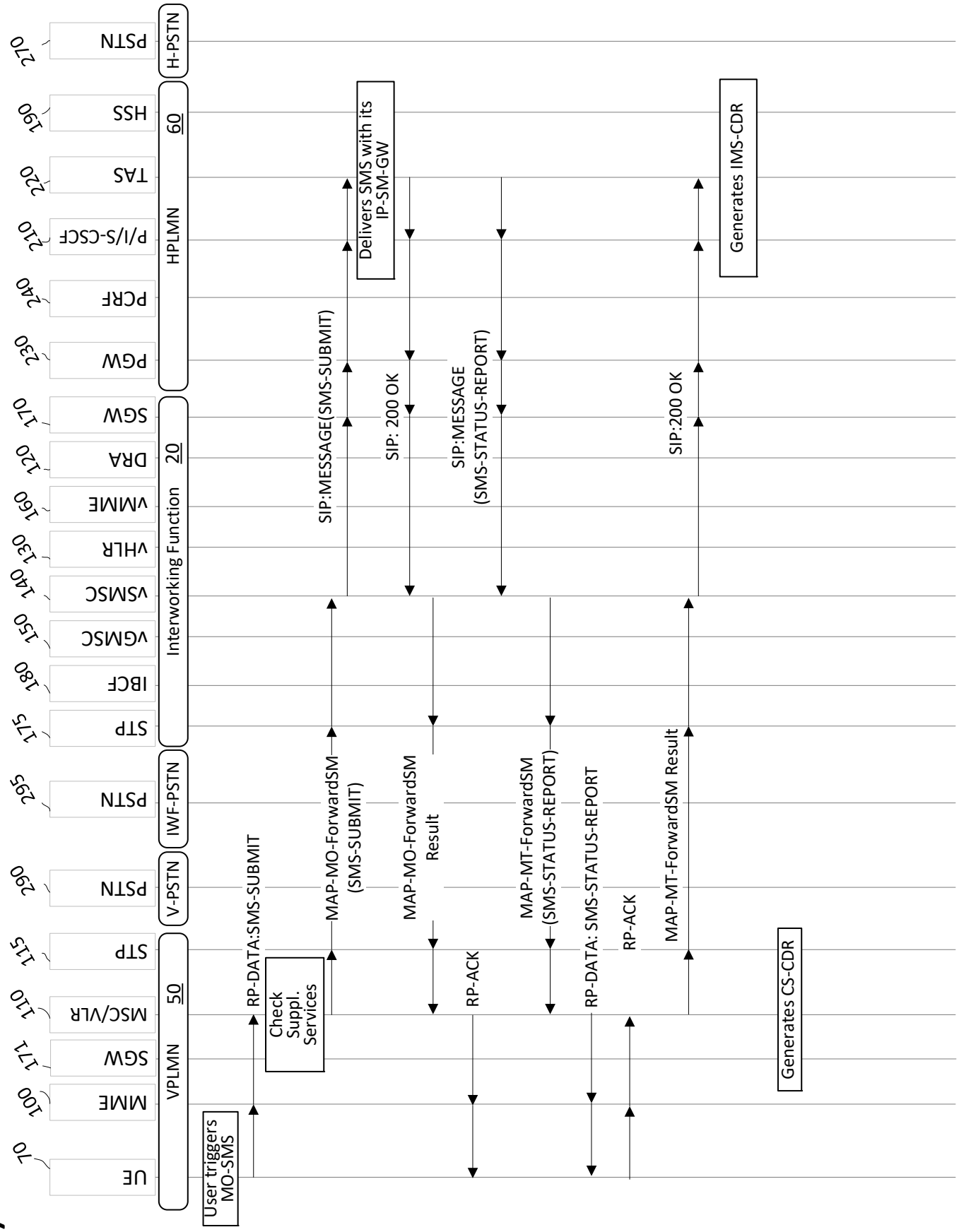
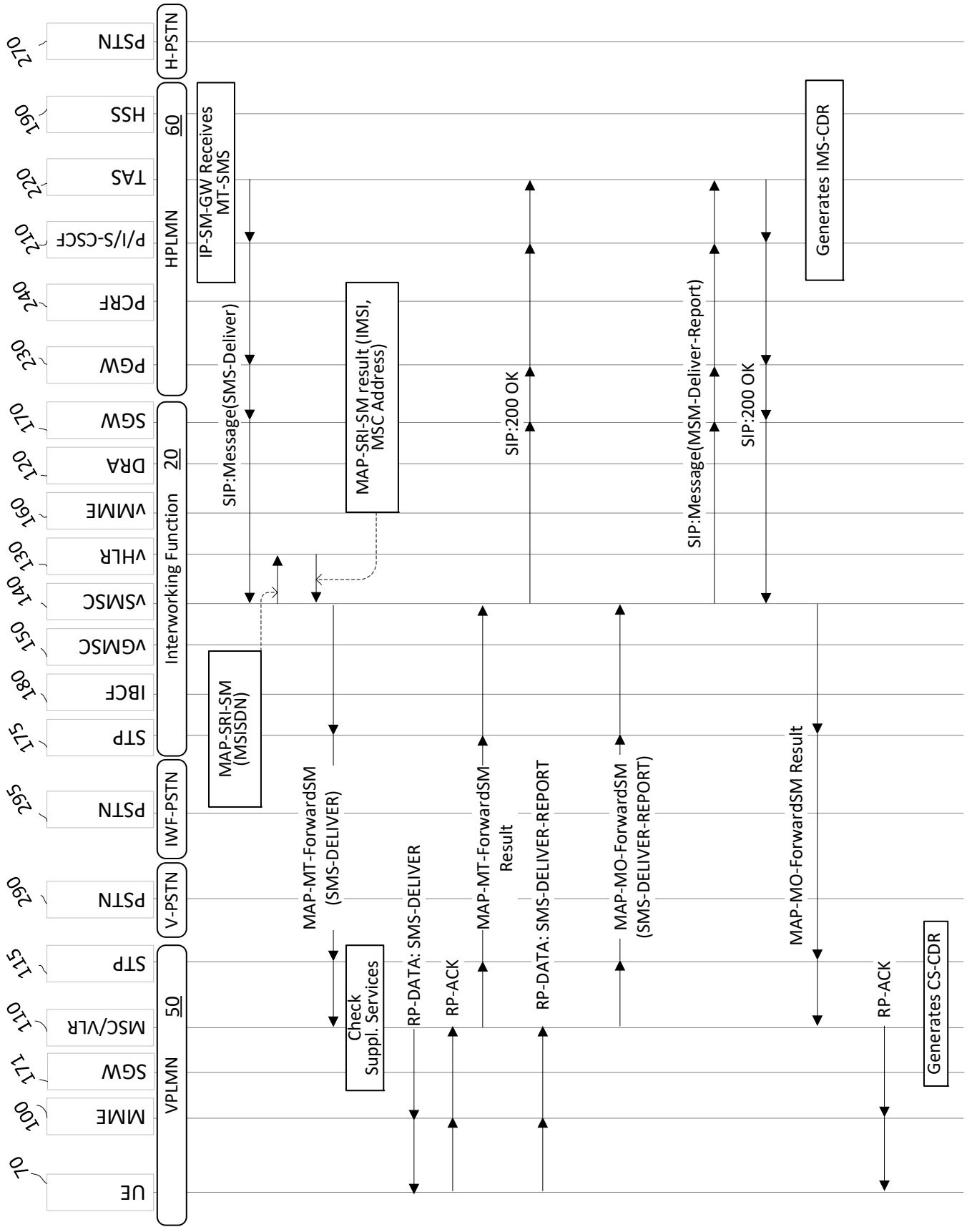

UE
MME
SGW
MSC/VLR
STP
V-PSTN
PSTN
IWF-PSTN
PSTN
STP
IBCF
vGMSC
vSMSC
vHLR
vMME
DRA
SGW
PGW
PCRF
P/I/S-CSCF
TAS
HSS
PSTN
70
100
171
110
115
290
295
175
180
150
140
130
160
120
170
230
240
210
220
190
270
VPLMN 50
Interworking Function 20
HPLMN 60
H-PSTN
User triggers MO-SMS
RP-DATA:SMS-SUBMIT
Check Suppl. Services
MAP-MO-ForwardSM (SMS-SUBMIT)
SIP:MESSAGE(SMS-SUBMIT)
Delivers SMS with its IP-SM-GW
MAP-MO-ForwardSM Result
SIP: 200 OK
RP-ACK
MAP-MT-ForwardSM (SMS-STATUS-REPORT)
SIP:MESSAGE (SMS-STATUS-REPORT)
RP-DATA: SMS-STATUS-REPORT
RP-ACK
MAP-MT-ForwardSM Result
SIP:200 OK
Generates IMS-CDR
Generates CS-CDR

Fig. 8


UE
MME
SGW
MSC/VLR
STP
PSTN
PSTN
STP
IBCF
vGMSC
vSMSC
vHLR
vMME
DRA
SGW
PGW
PCRF
P/I/S-CSCF
TAS
HSS
PSTN
VPLMN 50
V-PSTN
IWF-PSTN
Interworking Function 20
HPLMN 60
H-PSTN
70
100
171
110
115
290
295
175
180
150
140
130
160
120
170
230
240
210
220
190
270
IP-SM-GW Receives MT-SMS
SIP:Message(SMS-Deliver)
MAP-SRI-SM result (IMSI, MSC Address)
MAP-SRI-SM (MSISDN)
MAP-MT-ForwardSM (SMS-DELIVER)
Check Suppl. Services
RP-DATA: SMS-DELIVER
RP-ACK
MAP-MT-ForwardSM Result
RP-DATA: SMS-DELIVER-REPORT
MAP-MO-ForwardSM (SMS-DELIVER-REPORT)
SIP:200 OK
SIP:Message(MSM-Deliver-Report)
SIP:200 OK
Generates IMS-CDR
MAP-MO-ForwardSM Result
RP-ACK
Generates CS-CDR