On the Consideration of an UMTS/S-UMTS Based GEO-MSS System Architecture Design

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Abstract. To address the special requirements of China's future public satellite mobile network (PSMN), three system architecture schemes are proposed in this paper basing on different satellite payload processing modeling. Finally, one of them, i.e., the so-called passive part on-board switching based architecture, is selected as a proposal for further design and development of China's PSMN system, which essentially compatible to the 3GPP/UMTS R4 reference model.

Keywords: MSS, GEO, UMTS, network architecture.

1 Introduction

In order to extend and complement the current PLMN service coverage, to promote the emergency communications ability during disaster rescues, and to protect the rare space resource, that is, 115.5°E & 125.5°E S-band orbits, which China is holding with highest priority till now, the idea of establishing China's own public satellite mobile network (PSMN) has been proposed repeatly since the 3rd quarter of 2008. Several earlier fundings have been launched respectively by those related national divisions, among which the Ministry of Science and Technology of China (MSTC), is the most progressive one to start the relevant research and development activities.

So far, there are several mobile satellite systems which are already in sucessful commercial operation or right now under construction all over the world. The typical mobile satellite service (MSS) systems include: the 2G compatible systems, e.g., Iridium[1], Globalstar[2], Thuraya[3], ACeS; the 3G compatible system, i.e., the Inmarsat BGAN[4]; and so-called next generation system, i.e., MSV[5], Terrestar[6]. Undoubtedly, these MSS systems will be provided as a beneficial basis of the design and construction of China's future PSMN.

Among the above mentioned satellite systems, though some are successful deploied systems, and some are even designed in advanced technologies as adopted in the terrestrial counterpart systems, none could definitely address the prerequistes imposed by the Ministry of Science and Technolgy of China (MSTC). According to MSTC, the future PSMN should: first, base on 3G or 3G beyond techinology; and second, support a limited number of shorter-latency voice service real-time links, if not the whole. In this situation, a research group was organized by MSTC to setup the

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early stage work, in which we as a member mainly focus on the system network architecture design.

This paper is organized as following, section 2 lists the PSMN system main design features, network domains partition, and satellite payload configurations; section 3, 4 and 5 discribe three architecture schemes based on different satellite processing models; section 6 evaluates those three schemes, and makes a final decision; and finally, section 7 gives out a short summary.

2 System Description

2.1 Main System Features

In general, the PSMN system we are designing is nevertheless a typical satellite communications system, as illustrated in Fig.1.

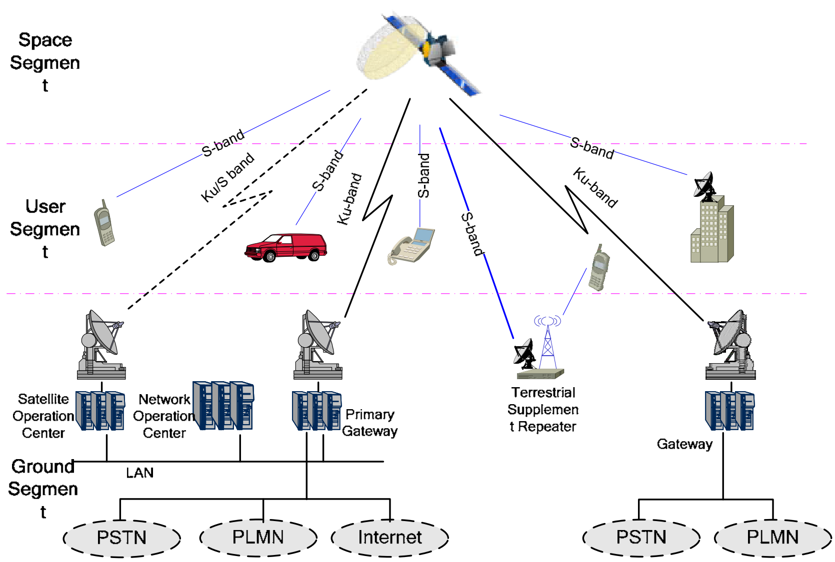

Fig. 1. The PSMN system organization diagram

There are several main design features of PSMN which should be listed before the system network architecture is described. These relevant features range from satellite orbit selection to communications technology evaluation, as well as radio interface decision.

- ***GEO orbits*****:** mainly due to the requirement of the satellite network file approved by ITU in 2004, the GEO orbits will be chosen for the PSMN of China, which will reduce the system complexity to some extent, but result in longest transmiting latency[7];

- ***3G Technology*****:** it is one of the prerequistes imposed by the MSTC to design a 3G compatible mobile satellite telecommunications system, which can provide higher data rate sevices, not only the low rate voice sevice;
- ***WCDMA Air-interface*****:** since applying CDMA2000 will suffer the patent problems, meanwhile TD-SCDMA is difficult to be employed within the satellite based system, the WCDMA becomes an appropriate choice of the system air-interface;
- ***3GPP R4 Reference Model*****:** among the 3GPP/UMTS releases, namely, Release 99, 4, 5, 6, 7, 8, 9 and 10, the R4 release[8] includes a mature and stable network architecture version, which is divided into RAN and CN fields, CS and PS domains, and most importantly, has a bearer independent CN;
- ***CN indepentent to PLMN*****:** the lowest integration level of satellite communications system and terrestrail tele-communications systems has to be chosen in China, for the licenses of the 3G telecommunications service were issued respectively to different operators, i.e., China Mobile, China Unicom and China Telecom.

2.2 Network Domains Partition

The Fig.2 shows the basic domains in UMTS network architecture.

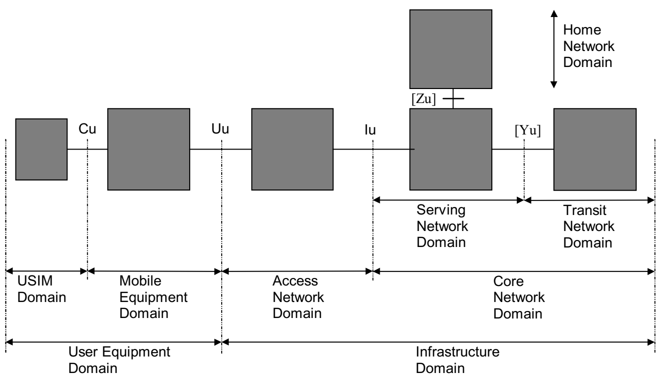

Fig. 2. The basic domains in UMTS network

where Cu is the reference point between USIM and ME; Iu is the reference point between Access and Serving Network domains; Uu is the reference point between User Equipment and Infrastructure domains, an UMTS radio interface; [Yu] is the reference point between Serving and Transit Network domains, and [Zu] is the reference point between Serving and Home Network domains.

To simplify the architecture design and description, a more general network partition model of the PSMN is illustrated in Fig.3, as following.

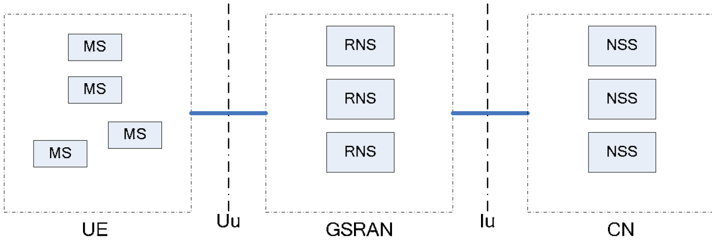

Fig. 3. Network domains partition model of the PSMN

where UE represents the user equipment domain, in which the MS is the mobile station; GSRAN represents the GEO satellite radio access network domain, in which RNS is the radio network sub-system; CN is the core network domain, in which NSS is the network switch sub-system.

2.3 Satellite Payload Configurations

As a MSS system, the satellite payload configuration becomes the key factor of the system network architecture design. In general, there are 5 possible payload configuration types, including,

- Transparent bent-pipe configuration
- Passive part on-board switching configuration
- Active part on-board switching configuration
- Passive full on-board switching configuration
- Active full on-board switching configuration

Anyway, those full on-board switching configurations couldn't be implemented under current technical level in China. To be practical, one of the other three configurations will be the optimal choice. More details on these three configurations and related system architecture designs will be presented and discussed in the following sections.

3 Transparent Bent-Pipe Based Scheme

The transparent bent-pipe model is the simplest model for satellite processing. It is divided into 2 functional entities, i.e., ULPU (User Link Processing Unit) and FLPU (Feeder Link Processing Unit), which respectively interface with the User Link and Feeder Link, as illustrated in Fig.4. The processings here within the ULPU and FLPU, may be as simple as only playing the role of an amplifier of RF signals.

Based on above satellite payload modeling, the related system architecture can be simply organized, as showed in Fig.5. As we can see, this is compatible with the 3GPP/UMTS R4 architecture[9], meanwhile taking into account the impact of the space segment, namely, the satellite.

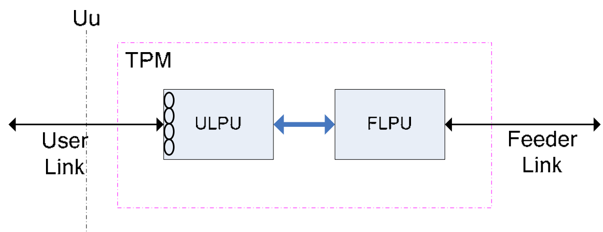

Fig. 4. Transparent bent-pipe model block diagram

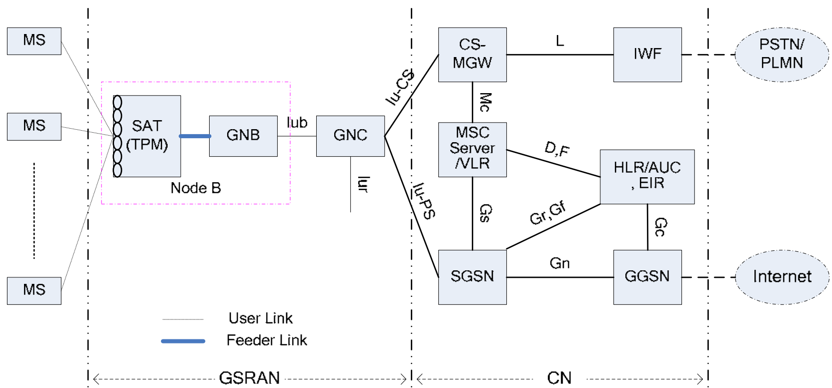

Fig. 5. Transparent bent-pipe based architecture scheme

As traditional UMTS/S-UMTS architecture, the network architecture of PSMN is also divided into two part, the Radio Access Network (RAN) and the Core Network (CN).

However, the RAN here is named as GSRAN (GEO Satellite Radio Access Network), since it is extended via the introduction of satellites in the high altitude space. The GSRAN consists of the following entities, such as, multi-spotbeam satellite, GNB (Gateway-station Node B), GNC (Gateway-station Network Controller). The GNB integrating with the transparent satellite together forms a terrestrial Node B entity. Thus, the GSRAN in total plays a role of UTRAN of the terrestrial celluar systems.

Likely, the CN in PSMN consists of those traditional functional entities, i.e., HLR (Home Location Register), VLR (Visitor Location Register), AUC (Authentication Center), EIR (Equipment Identity Register), MSC Server (Mobile-services Switching Center Server), CS-MGW (Circuit Switched-Media Gateway Function), IWF (Interworking Function), SGSN (Serving GPRS Support Node), GGSN (Gateway GPRS Support Node), etc. These entities act actuall the same as those in the terrestrial systems based on 3GPP/UMTS R4.

The communications procedure in this system will be the same as that in the 3GPP/UMTS system. However, since no on-board processing and switching, it can operates in double-hop communications mode.

4 Passive Part On-Board Switching Based Scheme

The passive part-switch on-board processing model is a hybrid model, mainly a transparent bent-pipe together with an capacity-limited on-board passive switch processing part. The passive switching here means that the on-board processor only executes switching function, while the routing control instructions come from other entities, e.g., those entitis in the ground segment. Obviously, the on-board switching is the only way to realize single hop voice communications links.

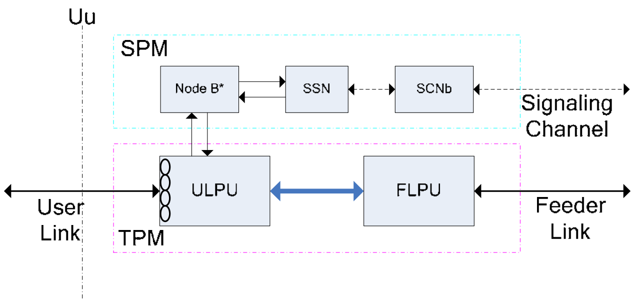

Fig. 6. Passive part-switch model block diagram

The passive part-switch model is illustrated in Fig.6, where the TPM means transparent processing module, and the SPM means switch processing module. The passive part-switch model comprises componets as following,

- **ULPU:** User Link Processing Unit
- **FLPU:** Feeder Link Processing Unit
- **Node B*:** Part-functional Node B on board;
- **SSN:** Satellite Switching Network on board;
- **SCNb:** Satellite Control Node-b, a control signaling interface node;

The network architecture above generally looks like the transparent bent-pipe case, except the introduing of a satellite control signaling branch. This branch consists of several new added functional entities in the PSMN system network architecture, as demonstrated in Fig.7,

1) GSRAN domain:

- **SCN** (Satellite Control Node): a node to control satellite payload, especially the on-board switching network;
- **SRC** (Satellite Route Controller): an entity to manage satellite switching resource and to decide the routing strategy;

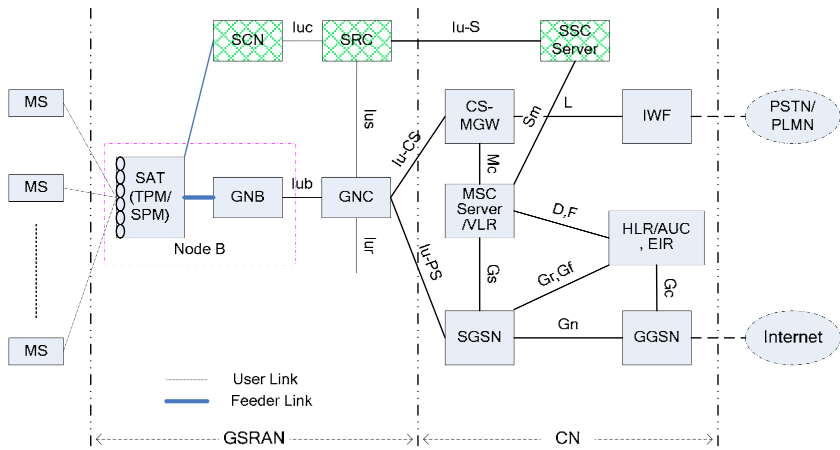

Fig. 7. Passive part on-board switching based architecture scheme

2) CN domain:

- **SSC Server** (Satellite Switching Coordination Server): an device to coordinate the necessary operations among the SRC and the MSC servers, e.g., charging.

There are also some new defined interfaces and related protocols in the PSMN system network architecture, including,

- **Iuc:** interface between SCN and SRC, with an also new defined interface protocol SCNAP (Satellite Control Node Application Part);
- **Ius:** interface between SRC and GNCs, with an also new defined interface protocol SRCAP (Satellite Routing Control Application Part);
- **Iu-S:** interface between SRC and SSC Server, with an also new defined interface protocol SSCAP (Satellite Switching Coordination Application Part);
- **Sm:** interface between SSC Server and MSC Servers, while using common CN interface protocol, such as MAP, BICC, etc.;

As to the communications procedure in this system, it will be much the same as that in the 3GPP/UMTS system, except that the voice traffic will be bypassed via the satelliter on-board processor after the calling setup, only if the SRC can find out enough on-board resource and issue an on-board switching instruction. By this way, single hop voice connectivity is realized.

5 Active Part On-Board Switching Based Scheme

Much like the passive part-switch model, the active part-switch model is also a hybrid model, except an on-board active switching processor instead of the passive one. The acttive switching means that the on-board processor not only executes switching function, but also fulfils single-hop routing, which is assumed to be the role of the ground segment of the system at the passive model.

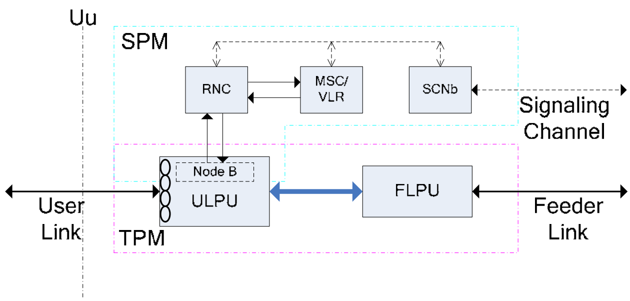

Fig. 8. Active part-switch model block diagram

The active part-switch model is illustrated in Fig.8. The TPM and SPM hold the same function as in the passive model. The active part-switch mode comprises the following components,

- **ULPU:** User Link Processing Unit
- **FLPU:** Feeder Link Processing Unit
- **Node B:** Full-functional Node B on board;
- **RNC**: Radio Network Controller on board;
- **MSC/VLR:** Mobile-services Switching Center/ Visitor Location Register on board;
- **SCNb:** Satellite Control Node-b, a control signaling interface node;

It should be noticed that in the active part-switch model, the Node-B entity on the satellite is embeded into the ULPU module as a portion of it.

The network architecture based on this on-board processor model is essentially the same as the passive one, while the later has a simpler satellite control signaling branch. The system network architecture is demonstrated in Fig.9,

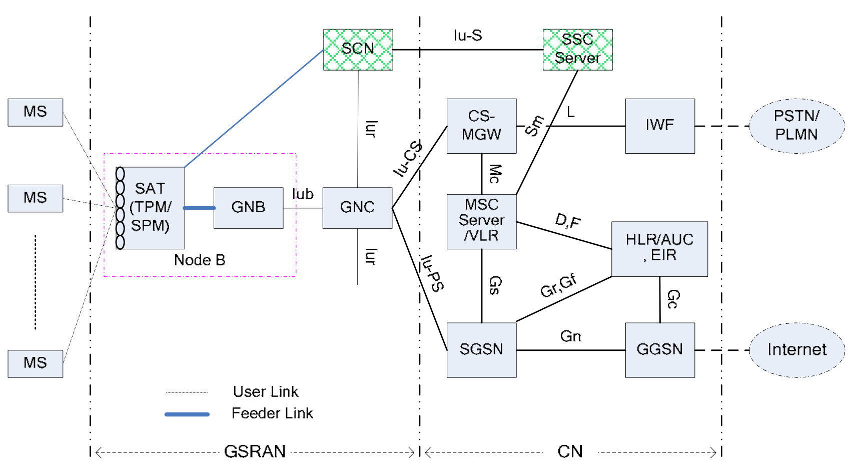

Fig. 9. Active part on-board switching based architecture scheme

1) GSRAN domain:

- **SCN** (Satellite Control Node): a node to control satellite payload. In contrast to the passive case, the SCN here mainly acts as the interfaces bridge between satellite and ground infrastructure parts, such as, Iur, Nc, E, & G;

2) CN domain:

- **SSC Server** (Satellite Switching Coordination Server): an device to coordinate the necessary operations among the On-board processor and the MSC servers, e.g., charging. On the other hand, SSC Server is also the interface converging point of the ground CN domain, which maintains the connectivities with the relevant CN functional entities on the satellite via the SCN.

There are less new defined interfaces and related protocols in this kind of PSMN system network, including,

- **Iu-S:** interface between SCN and SSC Server, with an also new defined interface protocol SSCAP (Satellite Switching Coordination Application Part);
- **Sm:** interface between SSC Server and MSC Servers, while using common CN interface protocol, such as MAP, BICC, etc.;

The communications procedure in this network architecture will be generally the same as that in the 3GPP/UMTS system, since the satellite can be treated as a small copy of the ground infrastructure. Meanwhile, the single hop voice links can be setup faster than in the passive scheme by this way.

6 Comparison and Discussion

Though the above 3 system architecture schemes are proposed for the China's PSMN, only one of them can be employed in the future. As we all know, the satellite processing capability is always the bottle-neck of the whole system, thus one scheme will be chosen basing on the comparison among 3 above mentioned satellite on-board processor models.

A brief comparison among the above 3 payload models is presented in the following Table 1. The comparing items are satellite payload resource usage, complexity, power comsump-tion, communications delay, link setup time, etc.

Table 1. A brief comparison among 3 models

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Models vs. Items	**Resource**	**Complxity**	**Power**	**Comm. delay**	**Setup time**
Trans. bent-pipe	Low	Low	Low	Large	Large
Passive part-switch	Medium	Medium	Medium	Small	Large
Active part-switch	High	High	High	Small	Small

As mentioned before, GEO system has a large transmission delay, i.e., about 0.27s for a loop, thus it will spend about 0.54s for the double hop mode. However, commercial real-time voice service generally requires less latency than 0.4s. To satisfy this requirement, single hop system is undoubtedly neccesary, which results in the inevitable satellite on-board switching[9].

Having considered these comparison results, together with the system design prerequistes in mind, we decide to apply the passive part-switch proceesing model based system network architecture as the basis of our further system design.

7 Summary

As a preparation of China's future PSMN plan, three system network architecture schemes are proposed in this paper for China's future GEO satellite mobile telecommunications system, which all are compatible to the 3GPP/UMTS R4 reference model. One of them, i.e., the passive part on-board switching based scheme, is selected finally basing on the comparison of their satellite on-board processing models, which in general addresses better the special design require-ments of the Ministry of Science and Technology of China.

However, the results presented here are schematic, and also simple to some extent. Further research efforts may focus largely on the detailed designs of the proposed entities, interfaces, protocols, and control procedures.

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