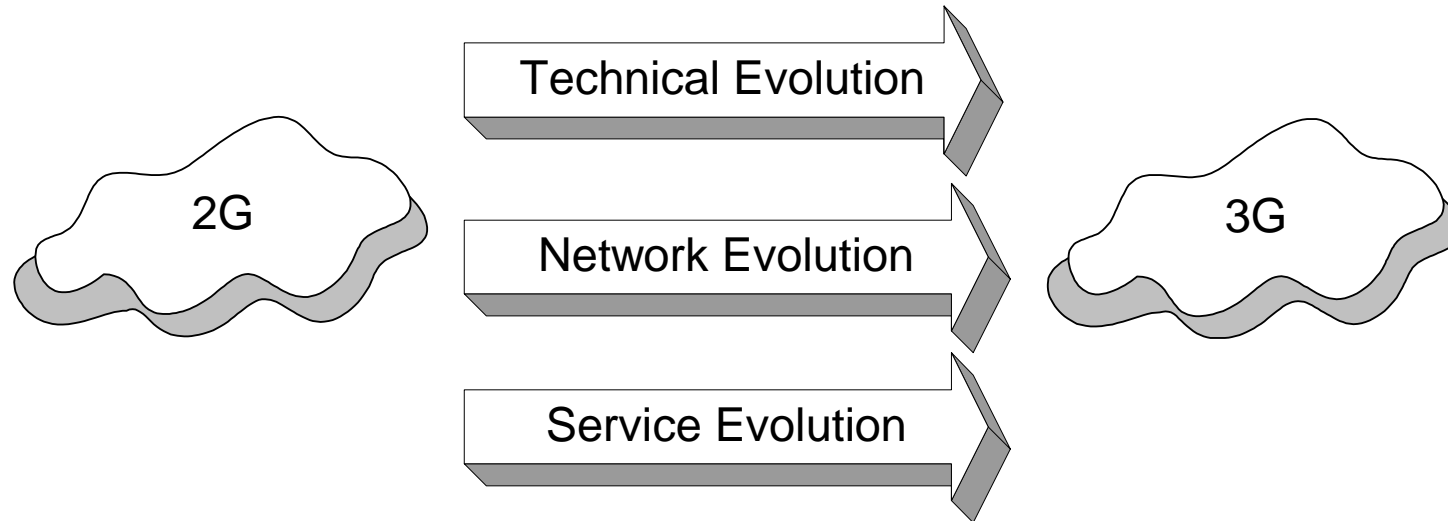# Evolution from GSM to UMTS

Outline of the lecture

- Evolutions form GSM to UMTS.
- 3G network architecture.
- Service provision in UMTS.

Evolution types

Technical Evolution

2G

Network Evolution

3G

Service Evolution

- Evolution contains not only technical evolution but also expansion to network architecture and services.
- Technical evolution: how network elements are developed and with witch technology.
- Network evolution: in result of network element evolutions the general functionality of the network is changing.
  - Technical evolution different for different vendors.
- Service evolution: demand generated by the end-users that can be supported by the technical features of the network.

Evolution of the wireless networks
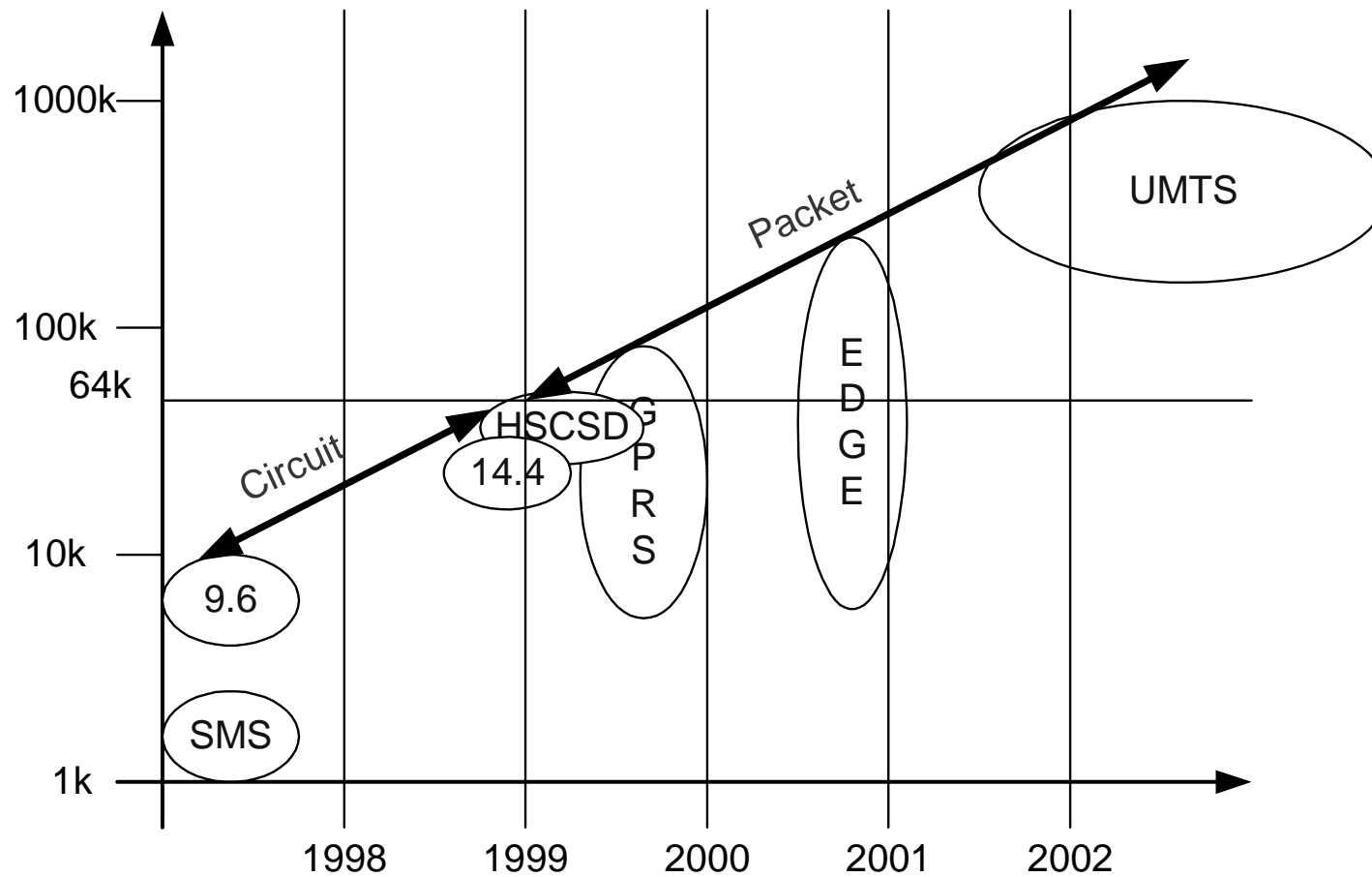
Basic GSM network (1)

- Driving idea in GSM: to define several open interfaces.
    - Operator may obtain different network components form different suppliers.
    - Strictly defined interface determines how the functions are proceeding in the network and which functions are implemented internally by the network element.
- GSM provides a means to distribute intelligence in the network. Network divided into four subsystems:
    - Network Subsystem (NSS): call control.
    - Base station Subsystem (BSS): radio path control.
    - Network Management Subsystem (NMS): operation and maintenance.
    - Mobile Station (MS).
- Difference between 1G and 2G:
    - Symmetric data transfer possibility.
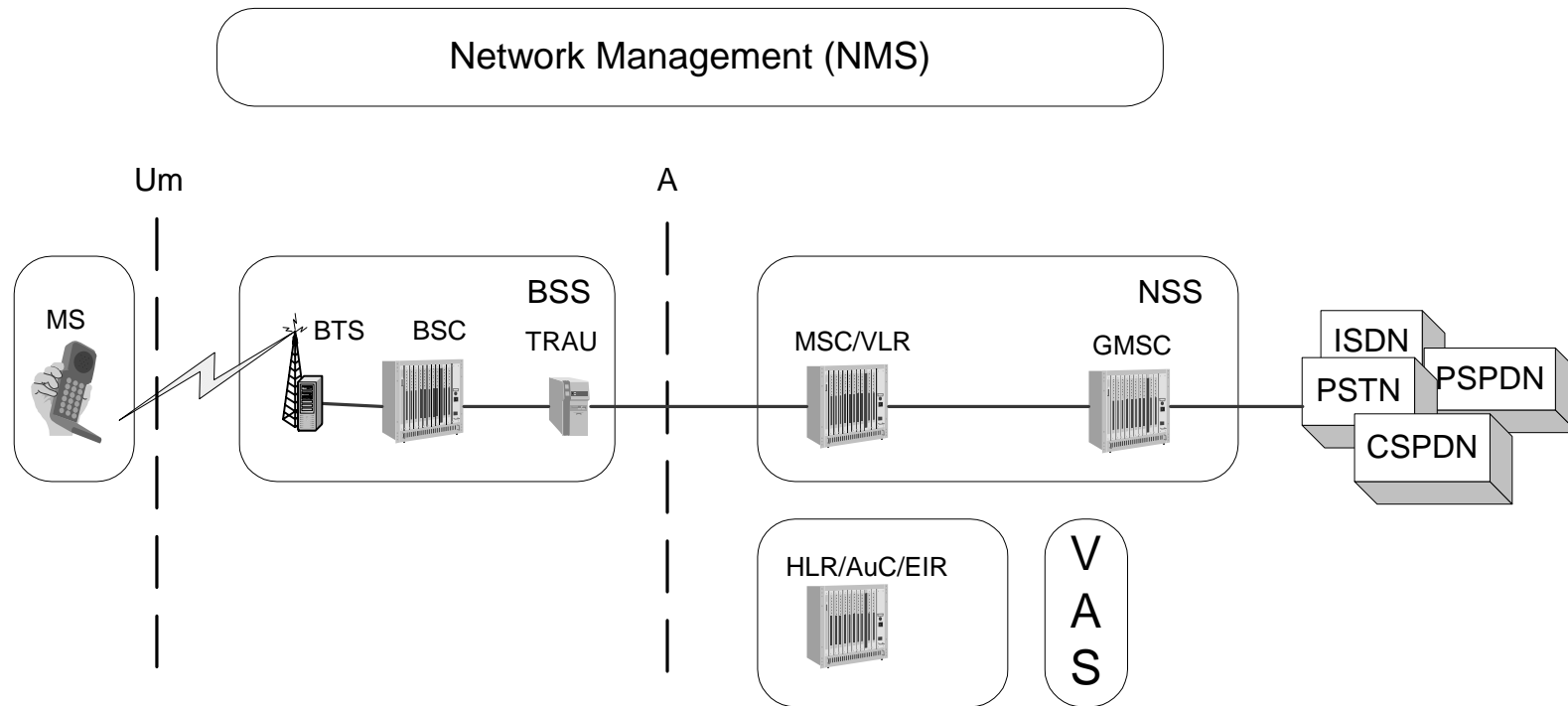   - Service palette adopted from Narrowband ISDN.

Basic GSM network (2)

Network Management (NMS)

Um

A

MS

BSS

BTS BSC TRAU

NSS

MSC/VLR GMSC

ISDN

PSTN PSPDN

CSPDN

HLR/AuC/EIR
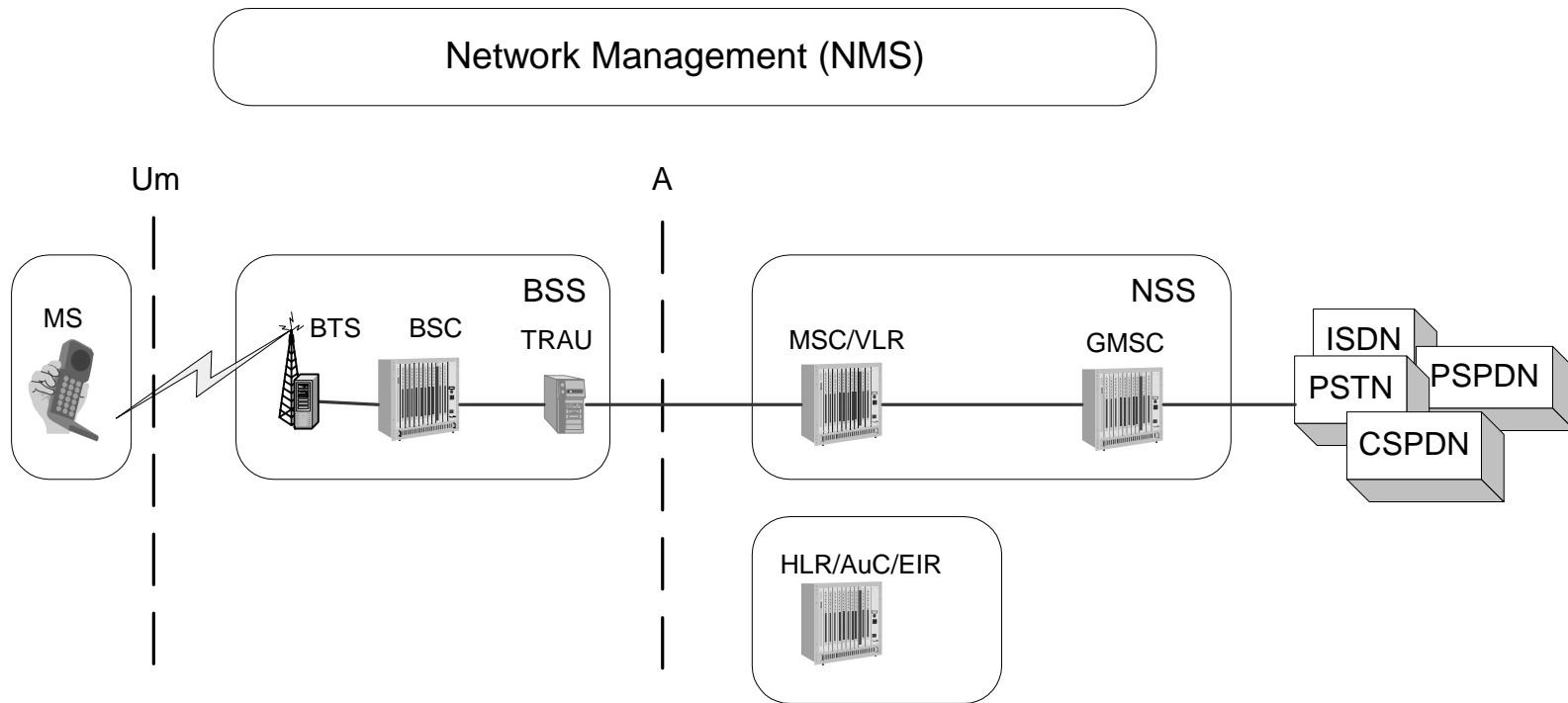
GSM Network elements

- MS: mobile equipment + subscriber data (Service Identity Module)
- Base Station Controller (BSC):
  - Maintains radio connections towards Mobile Station.
  - Maintains terrestrial connection towards the NSS.
- Base Transceiver Station (BTS):
  - Air interface signalling, ciphering and speech processing.
- Mobile Service Switching Centre (MSC):
  - Call control.
  - BSS control functions.
  - Internetworking functions.
  - Charging,
  - Statistics,
  - Interface signalling towards BSS and external networks.
- Serving MSC: BSS connections, mobility management, inter-working.
- Gateway MSC: Connections to the other networks.
- Visitor Location Register (VLR): local store for all the variables and functions needed to handle calls in the area related to VLR.

Value Added Service platform

Network Management (NMS)

Um

A

MS

BSS

BTS   BSC

TRAU

NSS

MSC/VLR

GMSC

ISDN

PSTN   PSPDN

CSPDN

HLR/AuC/EIR
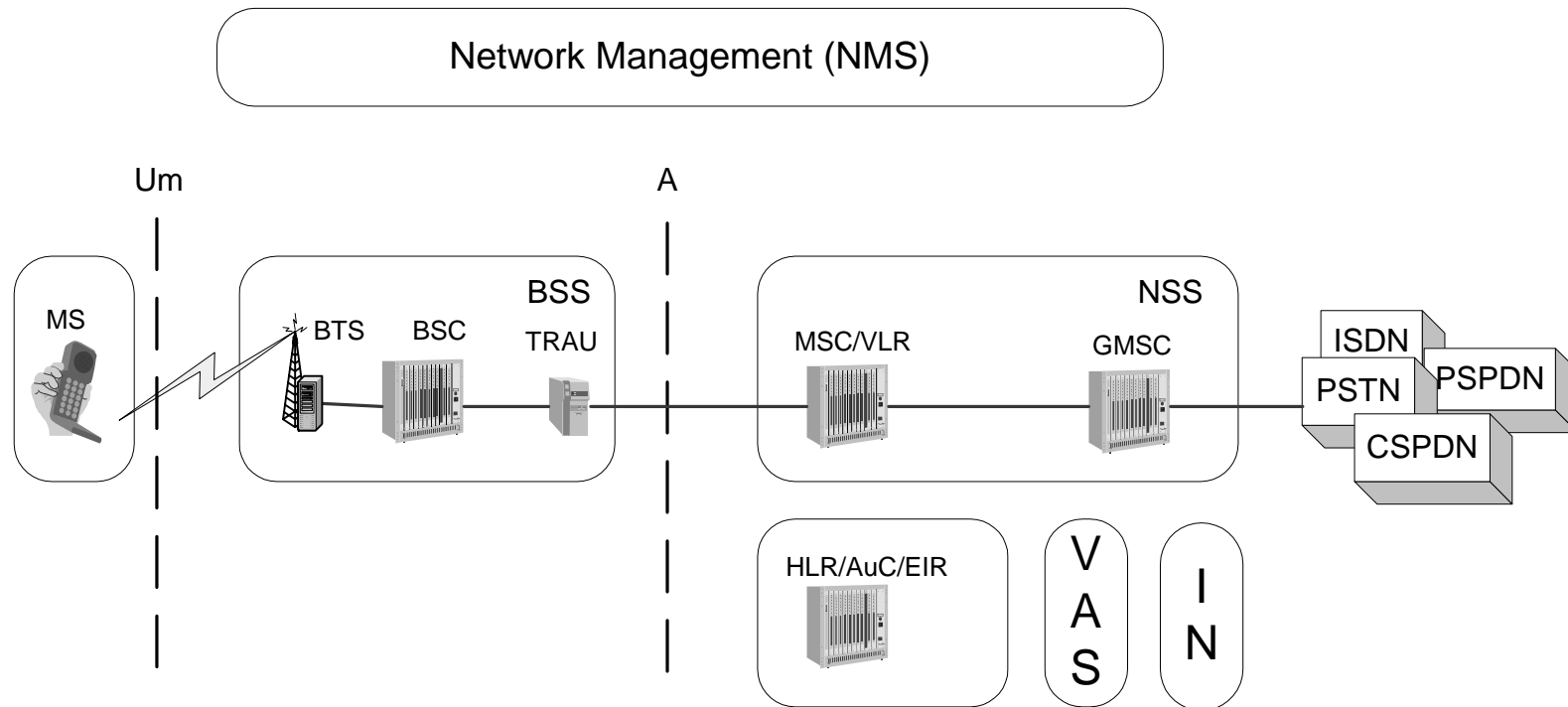
V
A
S

- Value Added Service (VAS) platform: simple platform for supporting certain type of services in GSM. (Short Message Service Centre (SMSC), Voice Mail System (VMS))
  - Use standard interface towards GSM. May or may not have external interfaces towards other networks.

Intelligent Network (IN)

Network Management (NMS)

Um

A

BSS

MS

BTS   BSC

TRAU

NSS

MSC/VLR   GMSC

ISDN

PSTN   PSPDN

CSPDN

HLR/AuC/EIR

V
A
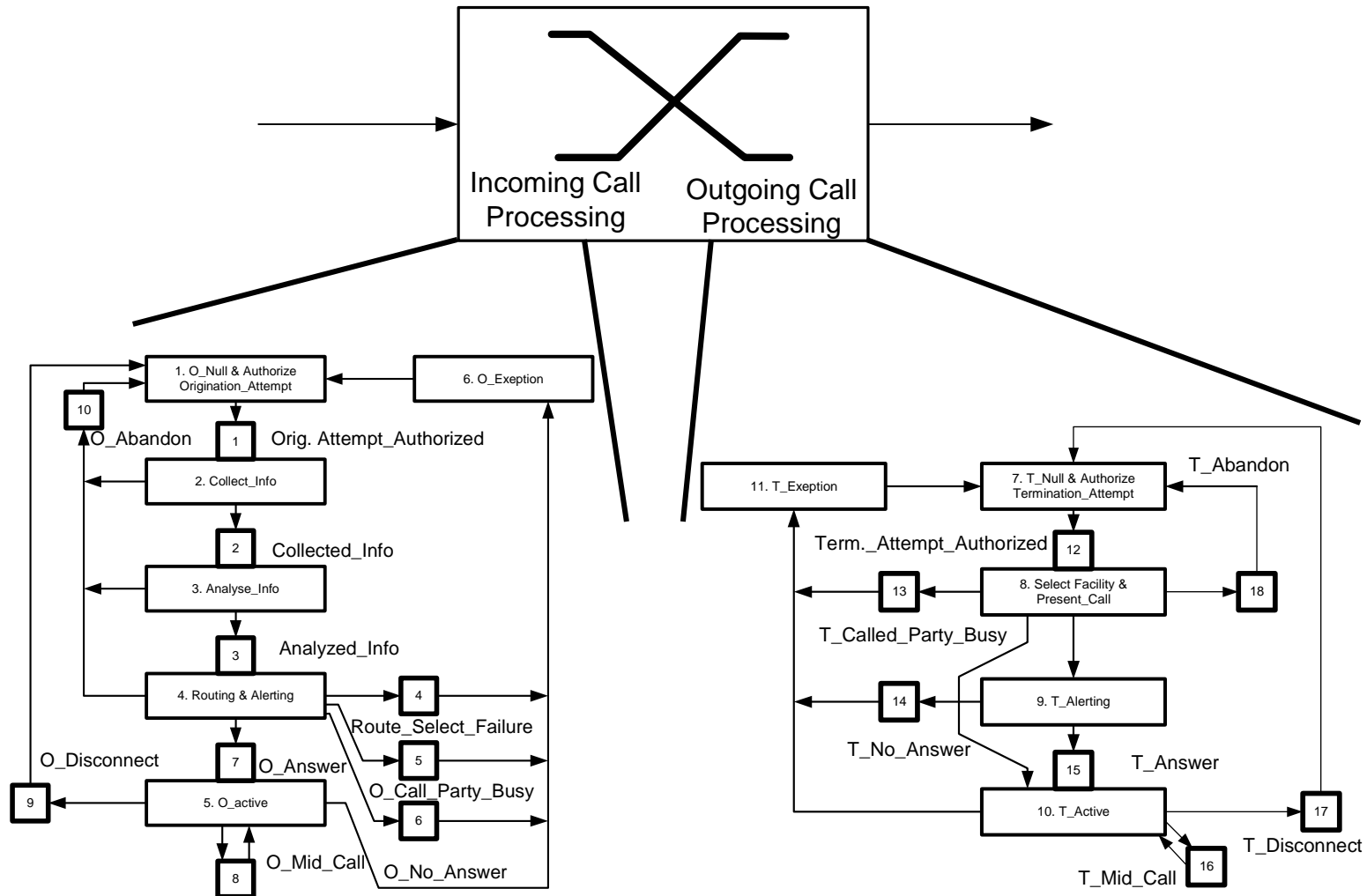S

I
N

- Intelligent network: a platform for creating and providing additional services.
  – Enables service evolution.
  – Changes in the GSM switching elements to integrate the IN functionality.
  – Example pre paid subscription.
- IN adopted from fixed network.
  – Not possible to transfer service information between networks.

IN CS-1 (capability set 1)

Incoming Call Processing   Outgoing Call Processing

Originating Basic Call State Model (BCSM) for CS-1

1. O_Null & Authorize Origination_Attempt

6. O_Exeption

10

O_Abandon   1   Orig. Attempt_Authorized

2. Collect_Info

2   Collected_Info

3. Analyse_Info

3   Analyzed_Info

4. Routing & Alerting

4   Route_Select_Failure

5   O_Call_Party_Busy

6   O_No_Answer

7   O_Answer

5. O_active

9   O_Disconnect

8   O_Mid_Call

Terminating BCSM for CS1

11. T_Exeption

7. T_Null & Authorize Termination_Attempt   T_Abandon

Term._Attempt_Authorized   12

13   8. Select Facility & Present_Call   18

T_Called_Party_Busy

14   9. T_Alerting

T_No_Answer

15   T_Answer

10. T_Active   17   T_Disconnect
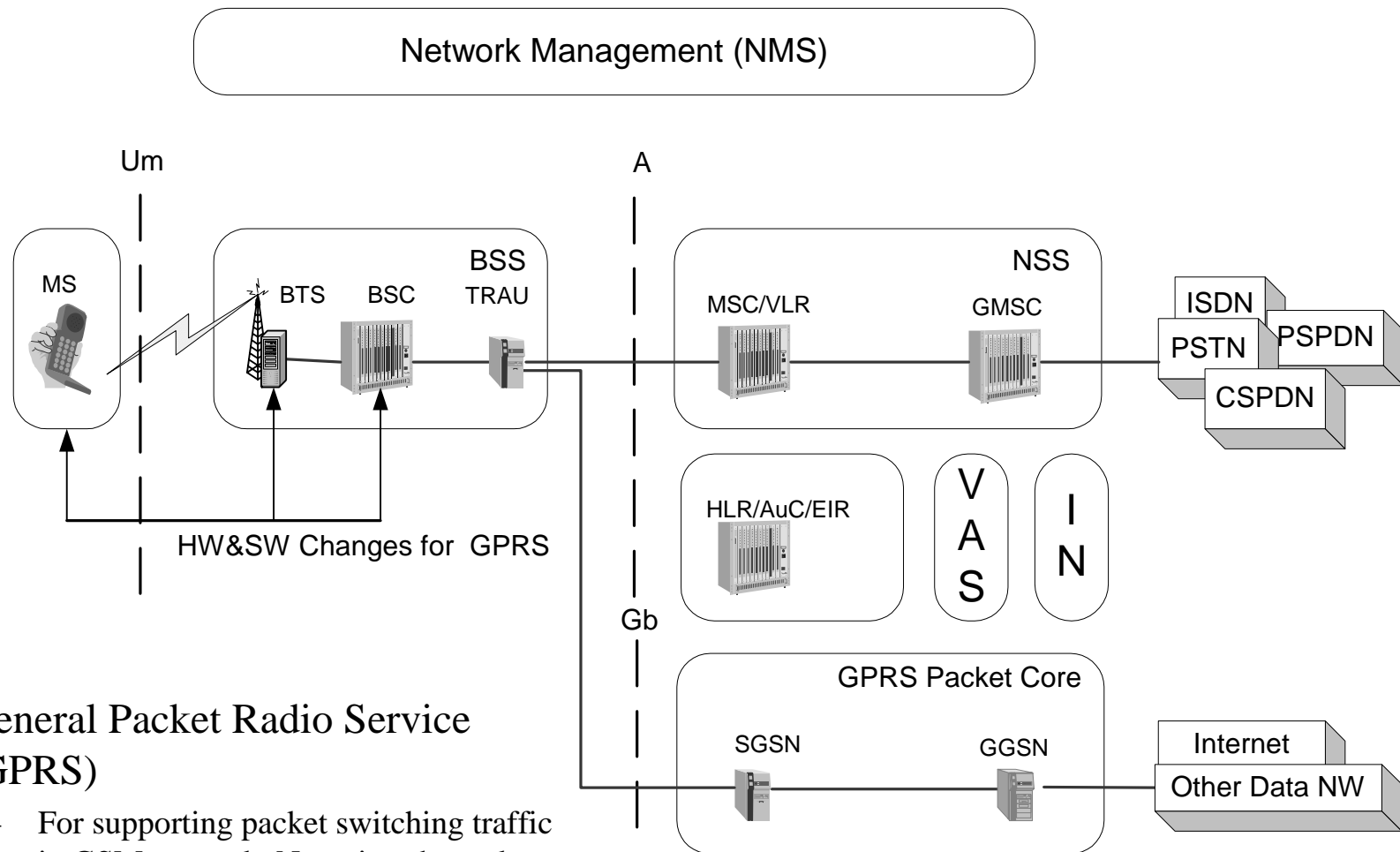
T_Mid_Call   16

BCSM

- BCSM is a high-level finite state machine description of call control function (CCF) activities required to establish and maintain communication paths for users.

- BCSM identifies points in basic call and connection processing when IN service logic instances are permitted to interact with basic call and connection control capabilities.

- Point In Call (PIC) identify CCF activities required to complete one or more basic call/connection states or interest to IN service logic instances.

- Detection Point (DP) indicate points in basic call and connection processing at which transfer of control can occur.

- Transition indicate the normal flow of basic call/connection processing from one PIC to another.

- Events cause transitions into and out of PICs.

HSCSD
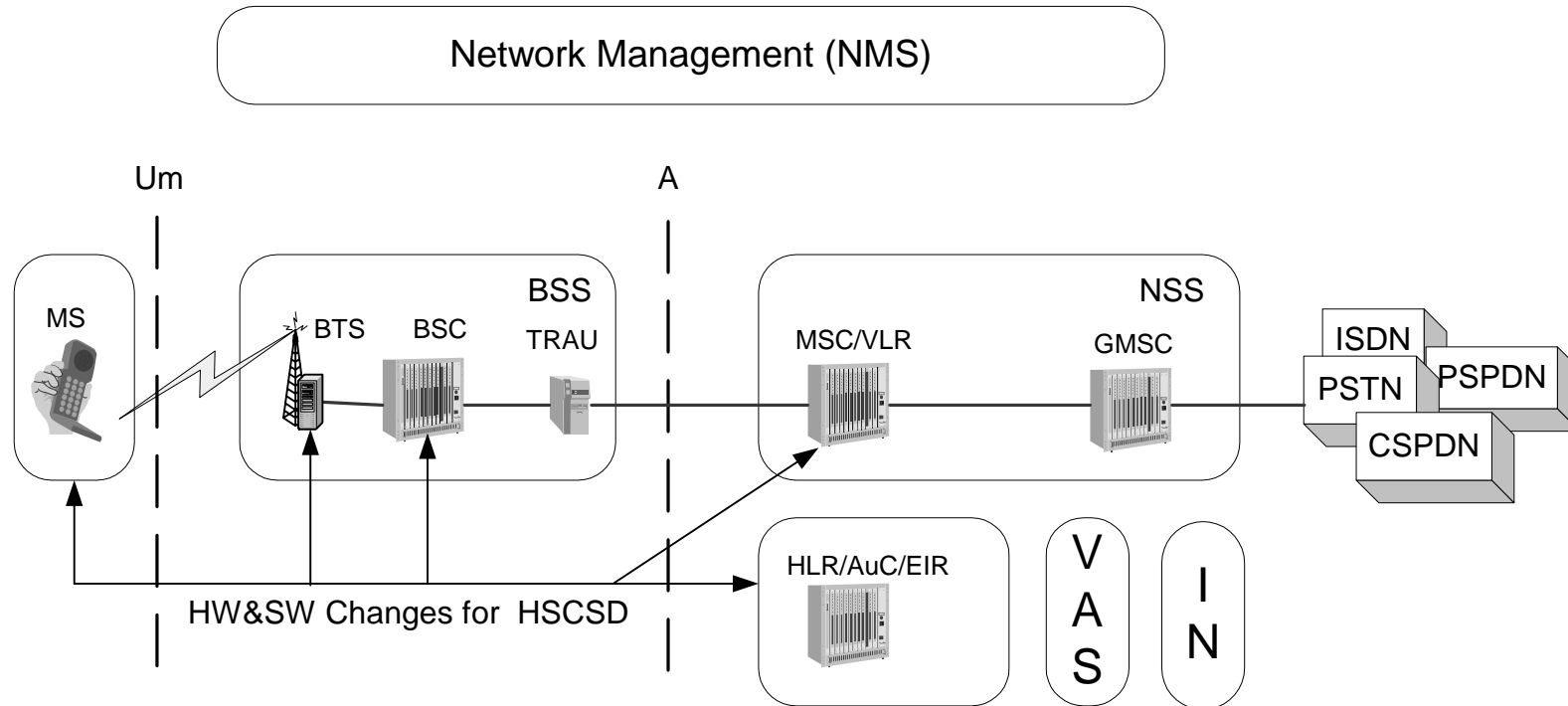
- The data throughput of the system is increased:
  - Channel coding is improved (9.6 kb/s -> 14 kb/s).
- High Speed Circuit Switched Data (HSCSD).
  - Several traffic channels can be used.
  - Max data rate 40 -50 kb/s.

GPRS

Network Management (NMS)

Um   A

MS

BSS

BTS BSC   TRAU

NSS

MSC/VLR   GMSC

ISDN

PSPDN

PSTN

CSPDN

HW&SW Changes for GPRS

HLR/AuC/EIR

V A S

I N

Gb

GPRS Packet Core

SGSN   GGSN

Internet
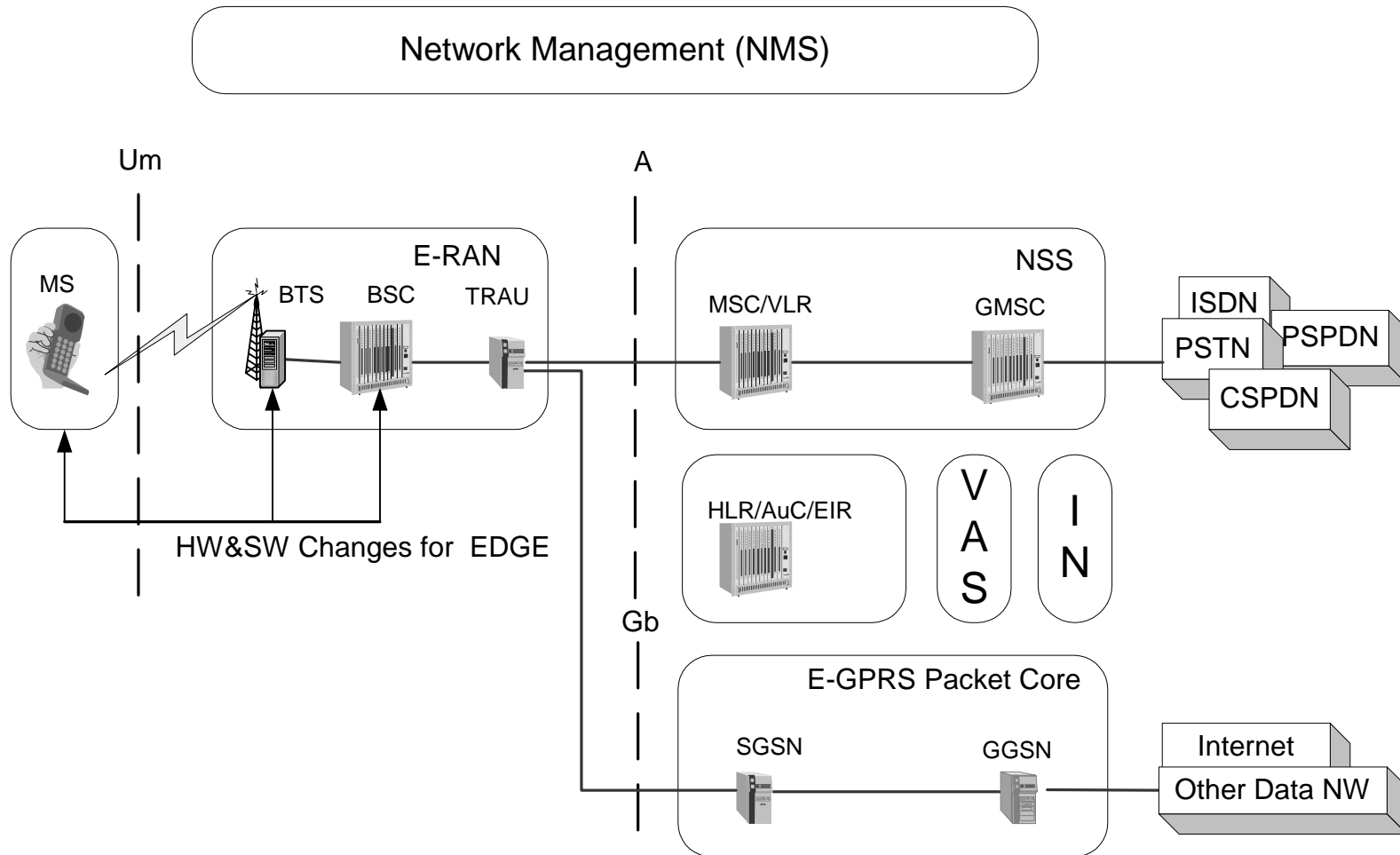
Other Data NW

- General Packet Radio Service (GPRS)
  - For supporting packet switching traffic in GSM network. No voice channel reservation.
  - Support for asymmetric traffic.

- Requires new service nodes:
  - Serving GPRS Support Node (SGSN).
  - Gateway GPRS Support Node (GGSN).

- Can not guarantee the QOS.

EDGE (1)

- Exchanged Data Rates for Global/GSM Evolution (EDGE):
  - New modulation scheme. (8 PSK)
  - Different coding classes. Maximal data rate 48 kbps per channel.
- EDGE phase 1:
  - channel coding and modulation methods to provide up to 384 kbps data rate.
  - One GPRS terminal gets 8 time slots. The channel should be good.
- EDGE phase 2:
  - Guidelines for achieving high data speed for circuit switching services.
- Data rates achieved almost equal to the ones provided by UMTS.
- Data rates not available everywhere in the cell.

EDGE (2)

Network Management (NMS)

Um

A

E-RAN

MS

BTS   BSC   TRAU

HW&SW Changes for EDGE

NSS

MSC/VLR   GMSC

ISDN

PSTN   PSPDN

CSPDN

HLR/AuC/EIR

V
A
S

I
N

Gb

E-GPRS Packet Core

SGSN   GGSN

Internet
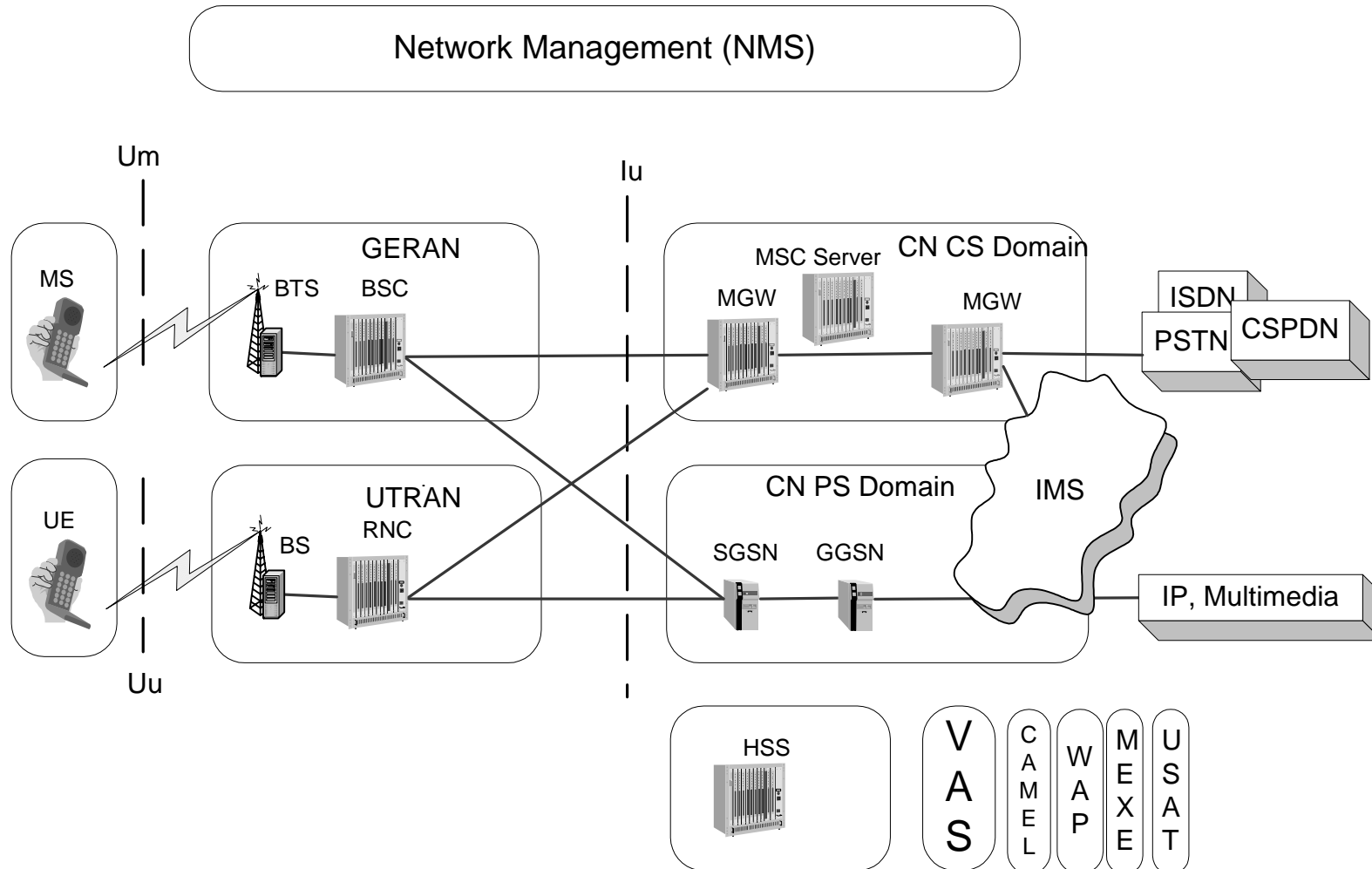
Other Data NW
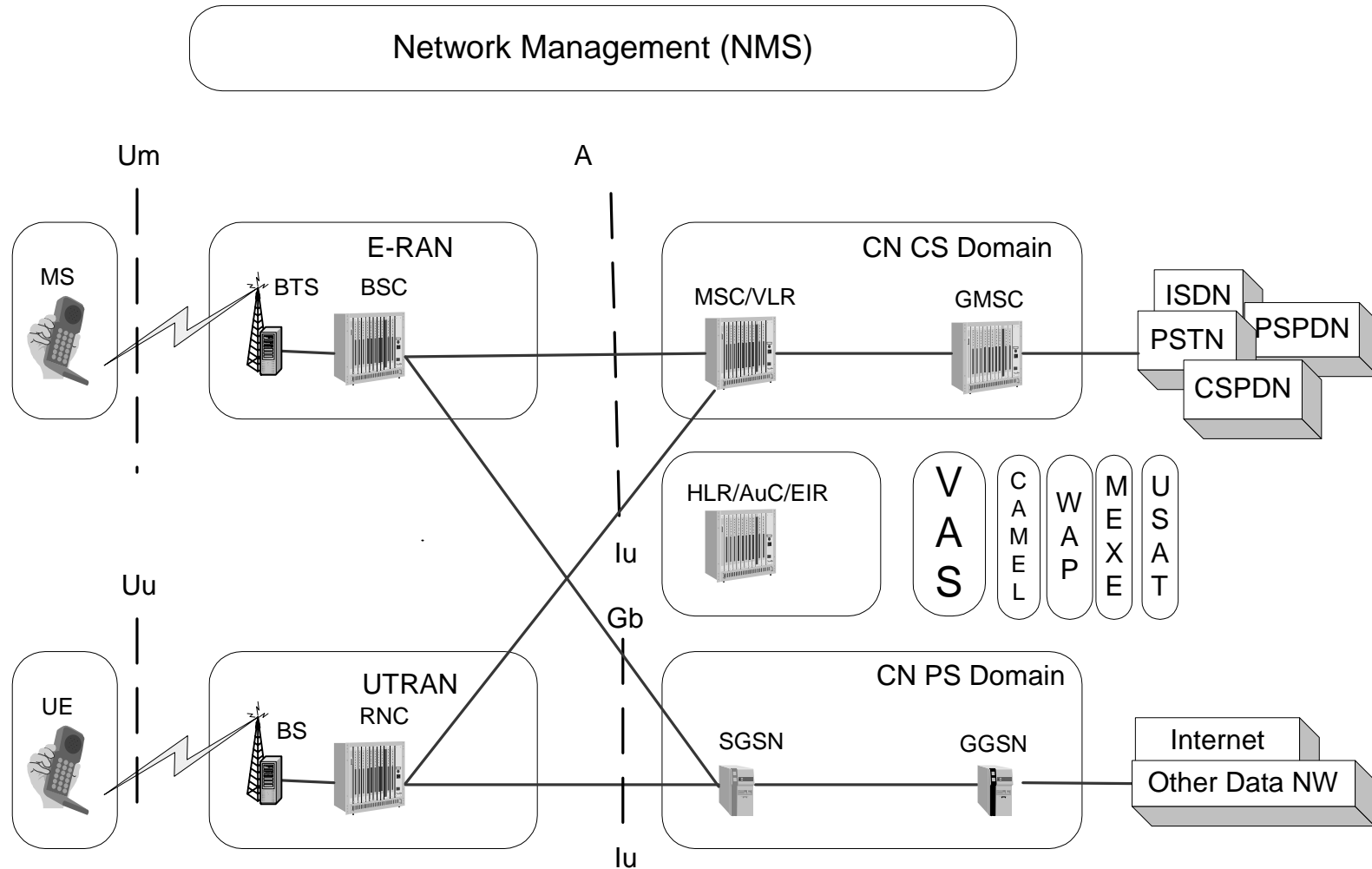
3G network R99 (1)

3G network R99 (2)

- New Radio interface.
- More suitable for packet data support.
- Interoperability with GSM:
  - GSM radio interface modified to broadcast CDMA system information. WCDMA networks transfer also GSM data.
  - Possibility to set 2G MSC/VLR to handle the wideband radio access, UTRAN.
- Customised applications for Mobile network Enhanced Logic (CAMEL):
  - Possibility to transfer service information between networks.
  - In the future almost CAMEL will be involved in all transactions between networks.

- CS domain elements are able to handle 2G and 3G subscribers.
  - Changes (upgrades) in MSC/VLR and HLR/AC/EIR.
  - For example SGSN
    - 2G responsible for mobility management (MM) for packet connections
    - 3G MM divided between RNC and SGSN.
- Services
  - Initially 3G offers same services as 2G.
  - Services transformed into PS domain.
- Trends
  - Separation of connections in control and services.
  - Conversion of the network towards all IP.
  - Multimedia services provided by the network.

3GPP R4 (2)

- The 3GPP R4 introduces separation of connection, its control, and services for CN CS domain.

- Media Gateway (MGW): an element for maintaining the connection and performing switching function when required.

- MSC server: an element controlling MGW.

- Packet switched voice (Voice Over IP).

  - The CS call is changed to the packet switched call in MGW.

  - For higher uniformity the CS and PS domain is mediated by IP Multimedia Subsystem.

- CAMEL will have a connection to the PS domain elements.

3GPP R4 (1)

Network Management (NMS)

Um

Iu

MS

GERAN

BTS   BSC

CN CS Domain

MSC Server

MGW   MGW

ISDN

PSTN   CSPDN

UE

UTRAN

BS   RNC

CN PS Domain

SGSN   GGSN

IMS

IP, Multimedia

Uu

HSS

VAS   CAMEL   WAP   MEXE   USAT

3GPP R5 (All IP)

Network Management (NMS)

Um

Iu

MS

GERAN
BTS   BSC
IP/ATM

UE

UTRAN
BS   RNC
IP/ATM

Uu

IP/ATM

CN PS Domain
SGSN   GGSN

IMS

ISDN
PSTN   CSPDN

IP, Multimedia

HSS

V A S   C A M E L   W A P   M E X E   U S A T
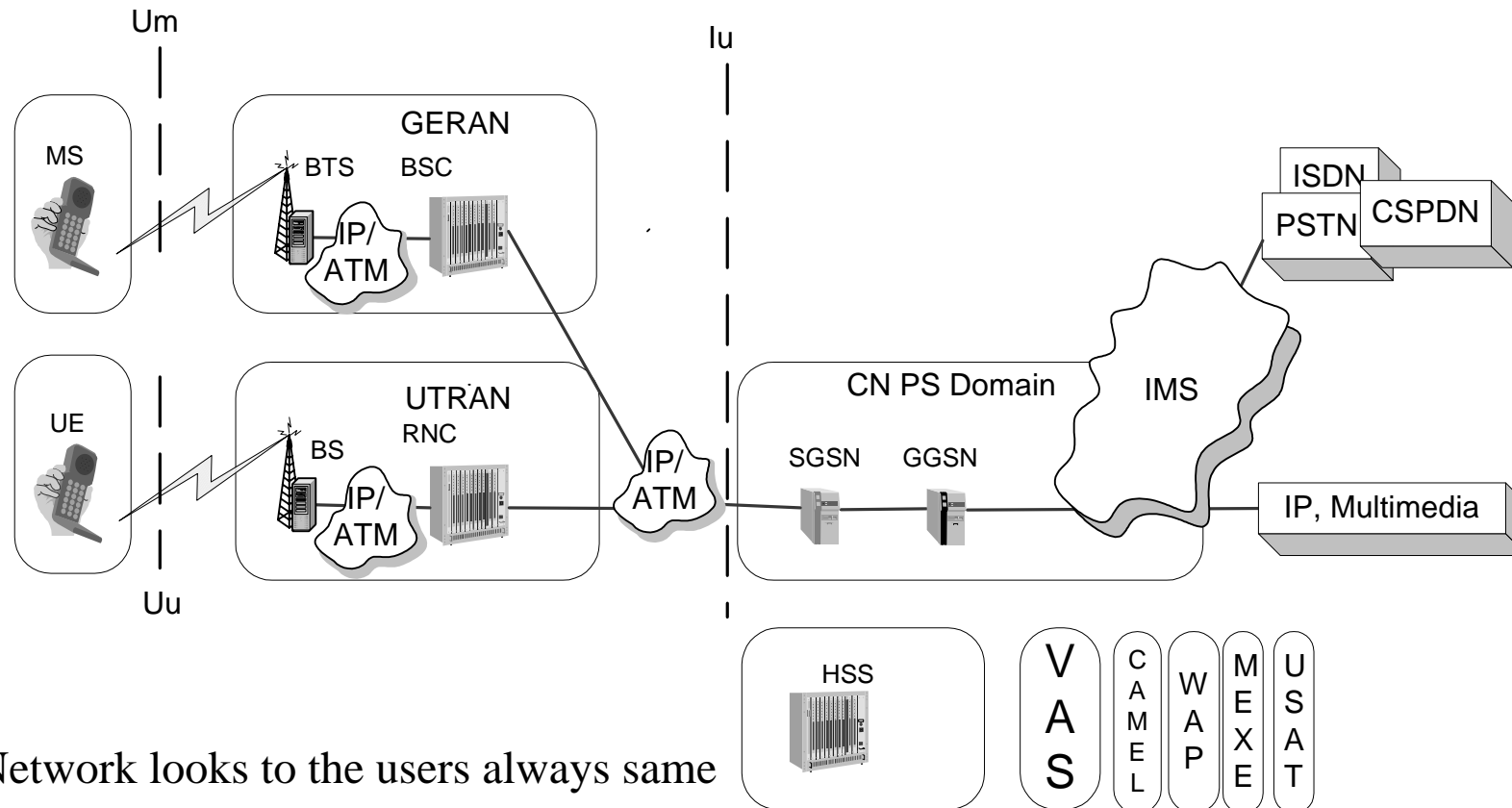
- Network looks to the users always same
  - Development inside the network
  - New transport technology: R99 ATM based; R4, R5 IP based.
- All traffic from UTRAN is supposed to be IP based.

Future trends

- Techniques:
  - Further separation of the user plane from the control plane.
  - Towards packet switching network.
  - Transparency of access technologies. Greater emphasis to services and quality.
  - 4G ?
    - Data rate ~20 Mbps (200 Mbps)
    - Self planning dynamic topologies.
    - Integration of IP.
  - OFDM
- Services
  - Location based services. Many services existing at the same time at different resolution.
  - Separation of users:
    - Commercial.
    - Private users.
    - Private users with specific needs.

3G Network architecture

- 3G is to prepare a universal infrastructure able to carry existing and future services.
- Separation of access technology, transport technology, service technology.
- The network architecture can be divided into subsystems based on the nature of traffic, protocol structures, physical elements.
- Conceptual network model
- Structural network model
- Resource management architecture
- UMTS service and bearer architecture

Conceptual network model

- Based on nature of traffic:
  - packet switched (PS)
  - circuit switched (CS)
- Domain is a highest level of group of physical entities and the defined interfaces between such domains. (3GPP spec. TR 21-905)
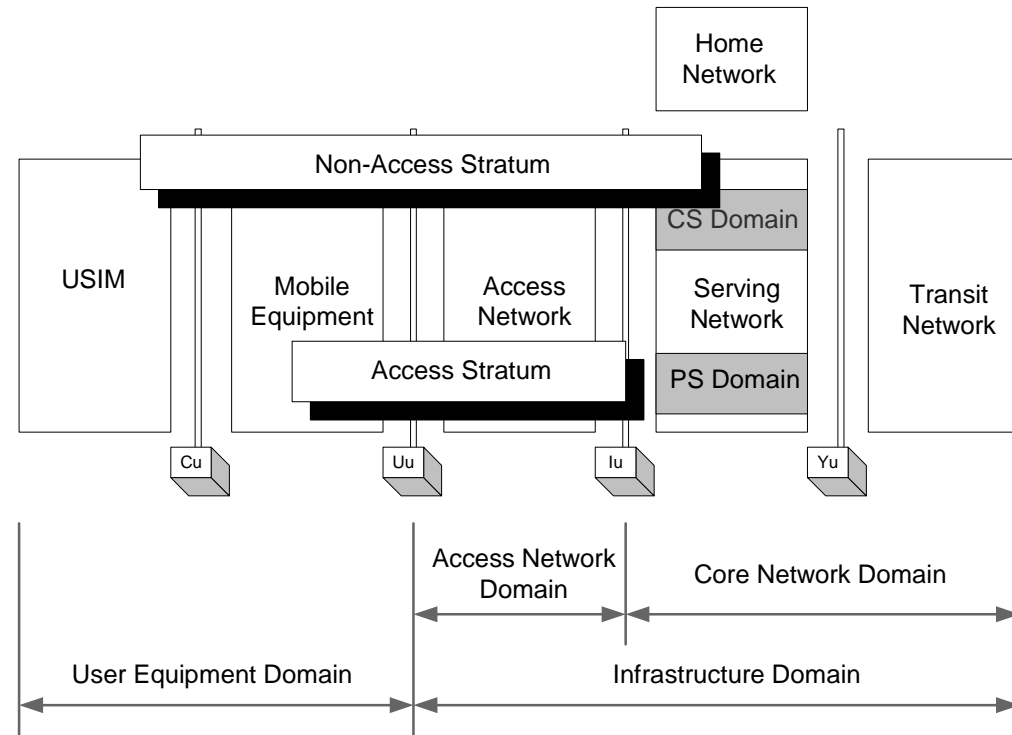
- Protocol structure and responsibilities divided as:
  - access stratum: protocol handling activities between UE and access network,
  - non-access stratum: protocol handling activities between UE and Core Network,
- Stratum is the way of grouping protocols related to one aspect of the services provided by one or several domains. (3GPP spec. TR 21-905)

UMTS architecture domains

User Equipment domain: dual mode and multi-mode handsets, removable smart cards … .

- Mobile Equipment (ME) domain:
    - Mobile Termination (MT) entity performing the radio transmission and related functions
    - Terminal Equipment (TE) entity containing the end-to-end application.
- User Service Identity Module (USIM) domain:
    - contains data and procedures to unambiguously and securely identify itself.

Infrastructure domains:

- Access network domain: physical entities managing the access network resources and provides the users with mechanisms to access the core network.
- Core network domain: physical entities providing support for the network features and telecommunication services: management of user location information, control of network features and services, switching and transmission.

Core network domains

- Serving Network (SN) domain representing the core network functions local to the user's access point and location changes when user moves.
- Home Network (HN) domain representing the core functions conducted at a permanent location regardless of the user's access point.
  - The USIM is related by subscription to the HN.
- Transit Network (TN) domain: the CN part between the SN and the remote party.

UMTS stratums

"Home Stratum"
USIM - HN
USIM - MT | MT - SN | SN - HN

"Serving Stratum"
USIM - MT | MT - SN

"Transport Stratum"
"Access Stratum"
MT - AN | AN - SN

USIM | MT/ME | Access Network Domain | Serving Network Domain | Home Network Domain

Application Stratum
Application

"Serving Stratum"
TE - MT | MT - SN

"Transport Stratum"
"Access Stratum"
MT - AN | AN - SN

TE | MT
Mobile Equipment Domain | Access Network Domain | Serving Network Domain | Transit Network Domain | Remote Party

Transport stratum

Supports the transport of user data and network control signalling from other strata through UMTS

- consideration of physical transport formats used for transmission.
- Mechanisms for error correction and recovery.
- Mechanisms to encrypt data over the radio interface and in the infrastructure part if required.
- Mechanisms for adaptation of data to use the supported physical format.
- Mechanism to transcode data to make efficient use of the radio interface.
- May include resource allocation and routing local to the different interfaces.
- The access stratum, which is specified to UMTS as the part of the trasnport stratum.

Access stratum

- Consists of User Equipment (UE) and infrastructure parts, as well as access-technique specific protocols between these parts.

- Provides services related to the transmission of data over the radio interface and the management of the radio interface to the other parts of UMTS.

The access stratum includes the following protocols:

- Mobile termination - Access network (MT-AN) protocol supporting transfer of detailed radio-related information to coordinate the use of radio resources between MR and AN.

- Access network - Serving Network (AN - SN) protocol supporting the access from the SN to the resources provided by the AN. It is independent of the specific radio structure of the AN.

Serving stratum

Consists of protocols and functions to route and transmit user of network generated data/information form source to destination. The source and destination may be within the same of different networks. It contains functions related to telecommunication services, and includes:

- USIM - Mobile termination (USIM - MT) protocol supporting access to subscriber-specific information to allow functions in the user equipment domain.

- Mobile Termination - Serving Network (MT -SN) protocol supporting access from MT to the services provided by the serving network domain.

- Terminal Equipment - Mobile Termination (TE -MT) protocol supporting exchange of control information between the TE and the MT.

Home stratum

- Consists of protocols and functions related to the handling and storage of subscription data and possibly home network specific services.

- Functions to allow domains other than the home network domain to act on behalf of the home network.

- Functions related to subscription data management and customer care, as well as billing and charging, mobility management and authentication.

The home stratum include the following protocols:

- USIM - Home Network (USIM - HN) protocol supporting co-ordination of subscriber-specific information between USIM and HN.

- USIM - Mobile Termination (USIM - MT) protocol providing the MT with access to user specific data and resources necessary to perform actions on behalf of the home network.

- Mobile Termination - Serving Network (MT - SN) protocol supporting user specific data exchange between the MT and the SN.

- Serving Network - Home Network (SN - HN) protocol providing the SN with access to HN data and resources necessary to perform its actions on behalf of the HN.

Application stratum

- It represents the application process itself, provided to the end user.

- It includes end-to-end protocols and functions making use of services provided by the home, serving, and transport strata and necessary infrastructure supporting services and/or value added services.

- The functions and protocols within the application stratum may adhere to GSM/UMTS standards or may be outside the scope of the UMTS standards.

- End-to-end functions are applications consumed by users at the edge of/outside the overall network.

- Authentication and authorised users may access the applications by using any variety of available user equipment.

Structural Network Architecture

- UE user equipment
- ME mobile equipment
- USIM UMTS Service Identity Module
- RAN Radio Access Network
  - UTRAM UMTS RAN
  - GERAN GSM/EDGE RAN
- Node B Base Station (BS)
- RNC Radio Network Controller
- RNS Radio Network Subsystem
- CS Core network
- Iur Interface between two RNS

Uu

UTRAN

Iu

CN

UE

BS

RNS

RNC

BS

UE

Iur

RNS

BS

RNC

BS

UE

CN CS Domain

3G MSC/VLR

3G GMSC

Registers

HLR/Au/EIR

CN PS Domain

SGSN

GGSN
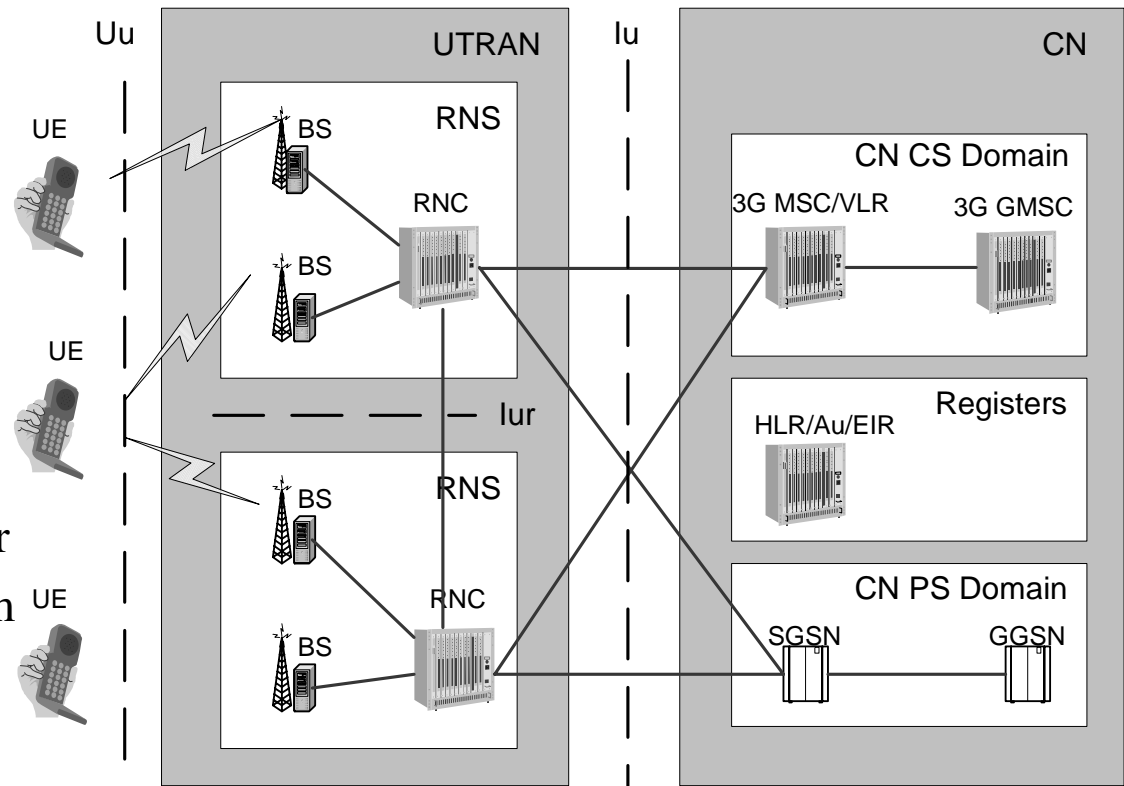
Resource Management Architecture

- Communication Management: functions and procedures related to the user connections.

- Mobility Management: functions and procedures related to mobility and security.

- Radio Resource Management: algorithms related to the radio resource.

- The functions are related to the control mechanisms:
  - Communication Control.
  - Mobility Control.
  - Radio Resource Control.
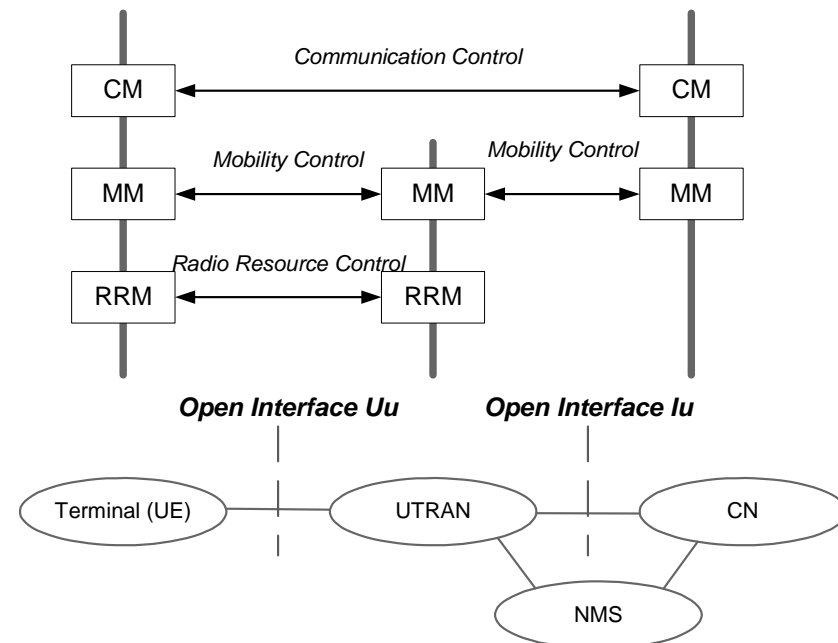
UMTS Services

- 3G is designed as platform for providing services
    - The lower location the layer has, the bigger is the investment in the network elements.

Content Provider layer	
Service Creation Layer	
Network Element Layer	
Physical Transmission Layer	

(Network Management on the left, Security Functions on the right of the stacked layers)

    - The higher location the layer has the bigger is the investment in people and ideas.

- Challenges: network management and securities.

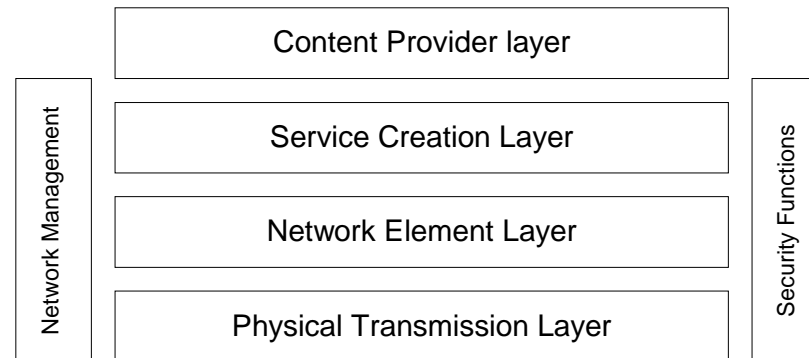- Methods for supporting service creation:
    - **Virtual Home Environment:** concept for personal service environment portability across network boundaries and between terminals.
    - **Mobile Station Execution Environment:** provides a standardised execution environment in an MS, and an ability to negotiate its supported capabilities with a MExE service provider, allowing applications to be developed independently of any MS platform.
    - **CAMEL** network feature: subscriber can use of Operator Specific Services (OSS) even when roaming outside the HPLMN.

Service Provision, user point of view

- The concept of the VHE is such that users are consistently presented with the same personalised features:

  - Personalised services.
  - Personalised User Interface (within the capabilities of terminals).
  - Consistent set of services from the user's perspective irrespective of access e.g. (fixed, mobile, wireless etc.) Global service availability when roaming.
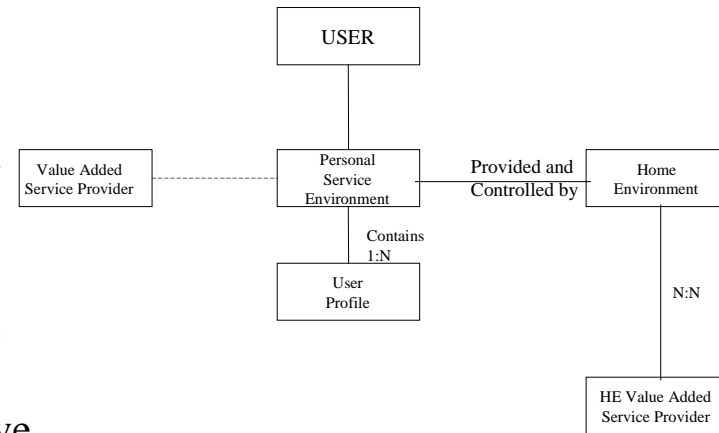
- The User's personal service environment is a combination of services and personalisation information (described in the user profile).
- The Home Environment provides services to the user in a managed way, possibly by collaborating with HE-VASPs, but this is transparent to the user.
- User may access services directly from Value Added Service Providers.

```
                                    ┌──────┐
                                    │ USER │
                                    └──────┘
                                        │
┌──────────────┐     ┌────────────┐  Provided and  ┌────────────┐
│ Value Added  │-----│ Personal   │  Controlled by │ Home       │
│Service Provider│   │ Service    │────────────────│Environment │
└──────────────┘     │Environment │                └────────────┘
                     └────────────┘                       │
                        Contains                          │
                          1:N                            N:N
                     ┌────────────┐                       │
                     │   User     │                ┌────────────┐
                     │  Profile   │                │HE Value Added│
                     └────────────┘                │Service Provider│
                                                   └────────────┘
```

Implementation of Services

Personal Service Environment

(Customised/Portable)

Applications/Clients
Built using Service
Capability Features

Proprietary
Service

Application Interface

Proprietary
Service
Capability
Feature

**Service
Capability Features**
*Accessible to Applications/Clients
via Standardised Application
Interface*

Proprietary
Service
Capability

**Service
Capabilities**
*Pre-set by Standards, e.g.
CAMEL, SAT, MExE, access to
bearers etc.*

Standardised

Applications / Clients

**Application
Interface**

ervice
apability
eatures (+)

**Service
capabilities**

SC 1   SC 2   SC 3   SC 4   SC n

GSM/GPRS/UMTS protocols, CAP/MAP(*)

Network

GSM/GPRS/UMTS protocol(*)

MS functionality, Standardized Services
API (e.g. MExE, SAT)

(*) ... standardised interfaces
(+) ... to be standardised

client2   ...   clientn

terminal view

- **Standardised Services:** Vendor specific implementation using standardised interfaces for service communication.

- **Operator Specific services:** Operator specific implementation of services by using vendor specific toolkits with standardised interfaces.

- **Other Applications:** implementions using standardised interfaces to the Service Capabilities (Bearers, Mechanisms). The functionality offered by the different Service Capabilities are defined by Service Capability Features.

- Within the terminals Service Capabilities are accessible via APIs, for example, MExE.

User Requirements for VHE

- The Personal Service Environment describes how the user wishes to manage and interact with their communications services.

- User Interface Profile:
  – Menu settings: menu items shown, menu structure, the placement of icons.
  – Terminal settings: ringing tone and volume, font type and size, screen and text colour, language, content types and sizes accepted.
  – Network related preferences: language used for announcements … .

- User Service Profile:
  – A list of services subscribed to and references to Service Preferences for each of those services if applicable.
  – Service status (active/deactive).

- Use could have more than one service profile.

Home environment requirements for VHE provision

- Control access to services:
  - depending on the location of the user, and serving network.
  - on a per user basis e.g subject to subscription.
  - depending on available service capabilities in the serving network, and terminals.
- Define the scope for management of services by the user, for services provided by the HE.
- Manage:
  - service delivery based on for example end to end capabilities and/or user preferences.
  - the prepaid accounts (e.g. increase, decrease the credit, or pass the information to an. application which manages the credit).
  - provision of services to users or groups of users.
- Request:
  - version of specific services supported in serving network and terminal.
  - details (e.g. protocol versions and API versions) of available service capabilities supported in the serving network, and terminals.
- Handle charging for services.
- Inform the serving network:
  - of the type of charging (i.e. prepaid or/and postpaid) for any required service.
  - of the threshold set for a given service required by the user and charged on a prepaid account.
  - how to manage a service for which the threshold has been reached.
- Deploy services to users or groups of users.

Serving Network requirements for VHE provision

The serving network should not need to be aware of the services offered via the home environment.

It shall be possible for the serving network to perform the following:

- The serving network shall support user access to services in the home environment.
- The serving network shall provide the necessary service capabilities to support the services from the home environment as far as possible.
- Dynamically provide information on the available service capabilities in the serving network.
- Provide transparent communication between clients and servers in terminals and networks.
- Request the charging information (type of charging, threshold for prepaid services and behaviour if the threshold is reached) for any service possibly required by the user.
- Handle the call according to the instructions received by the home environment regarding charging activities.
- Inform the home environment of the chargeable events.

Bearer Service

TE	MT	UTRAN	CN Iu EDGE	CN gateway

End-toend Service

Local Bearer Service	UMTS Bearer Service		External Bearer Service

Radio Access Bearer Service

CN Bearer Service

Radio Bearer Service	Iu Bearer Service	Backbone Bearer Service

UTRA Service	Physical Bearer Service	Backbone Phys. Bearer Service