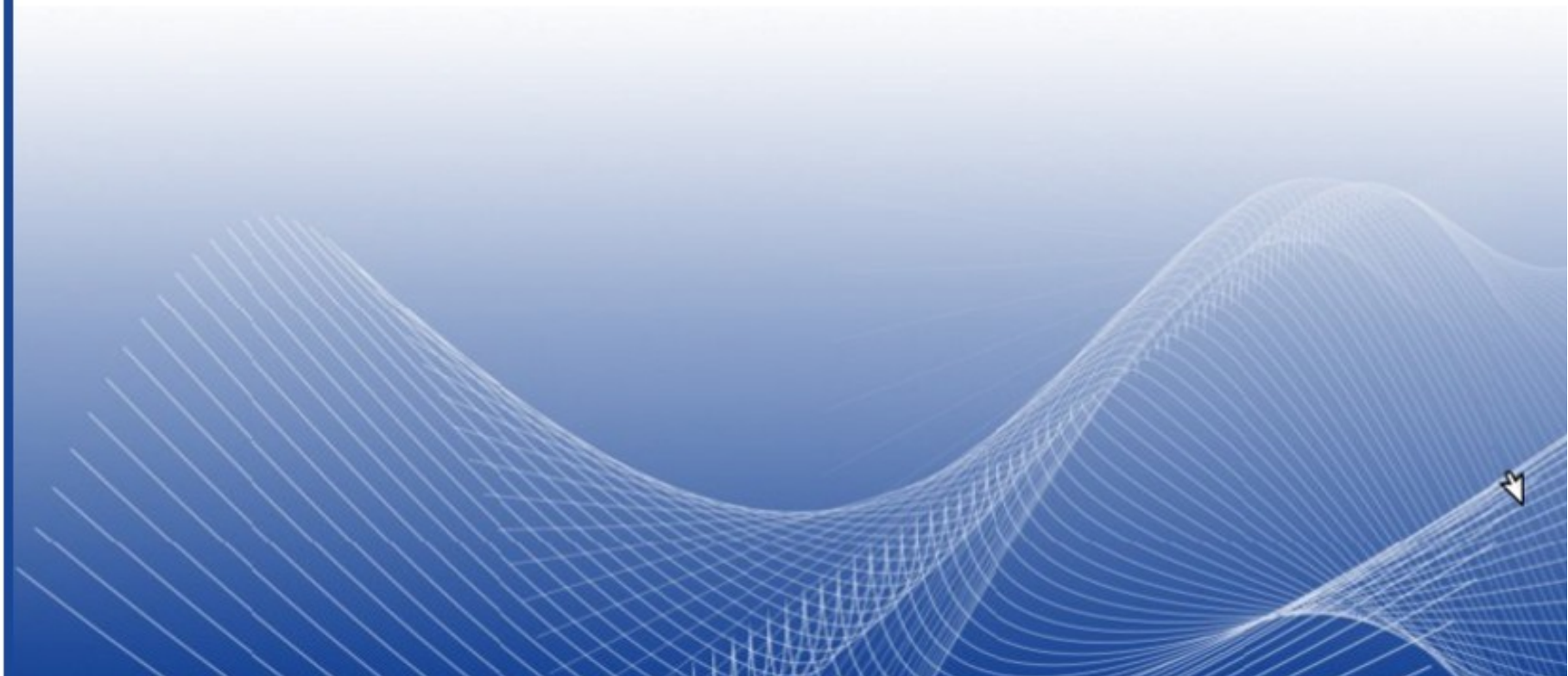
Mobile Networks

Arquitetura de Redes Avançadas



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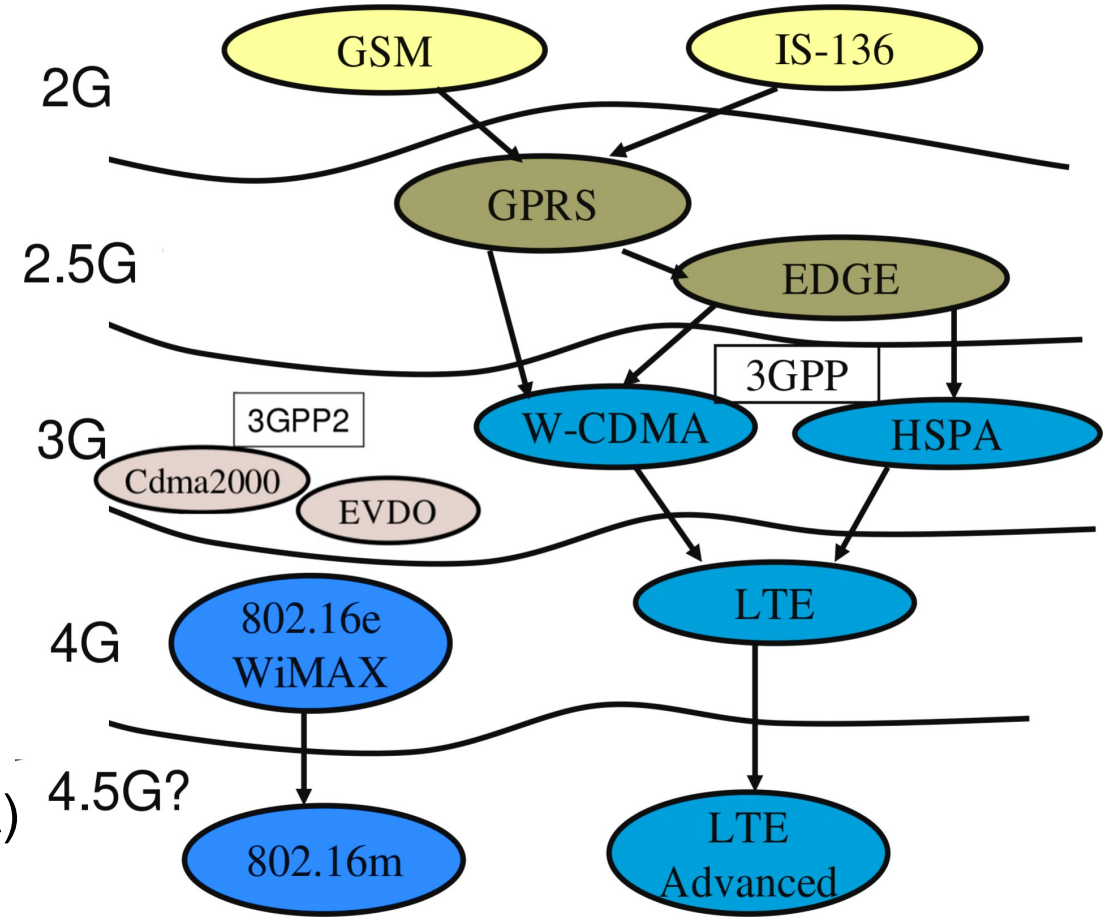
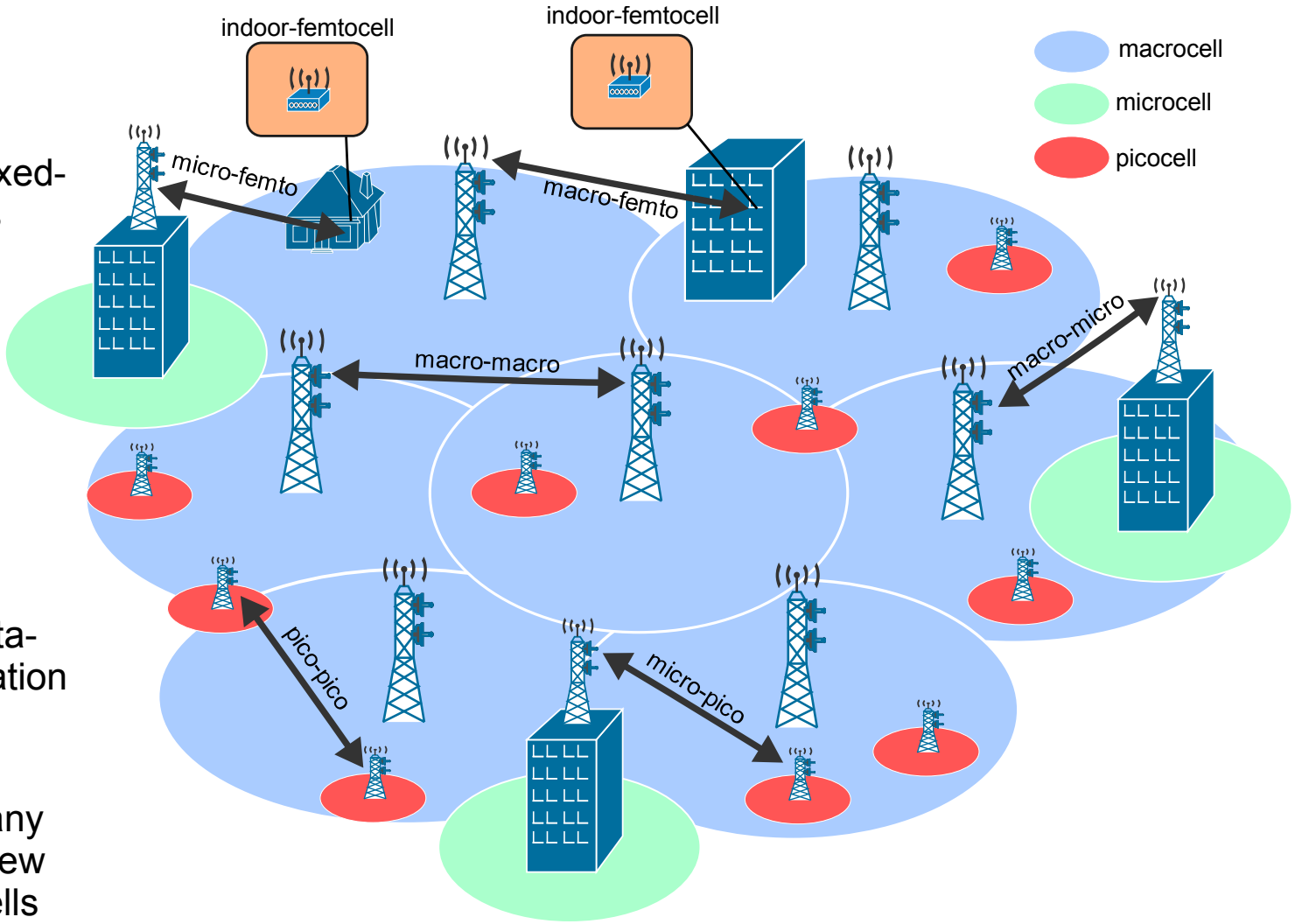
Mobile Networks

- 2G:
  - GSM (Global System for Mobile)
  - GSM Packet Radio System (GPRS)
  - Enhanced Data-rates for GSM Evolution (EDGE)
- 3G:
  - Universal Mobile Telecommunication System (UMTS)
    - Based on Wideband-CDMA (W-CDMA)
  - High Speed Packet Access (HSPA)
    - High-Speed Downlink Packet Access (HSDPA)
    - High-Speed Uplink Packet Access (HSUPA)
  - CDMA2000
- 4G:
  - LTE
  - LTE-Advanced
  - IEEE 802.16e (WiMax) and IEEE 802.16m

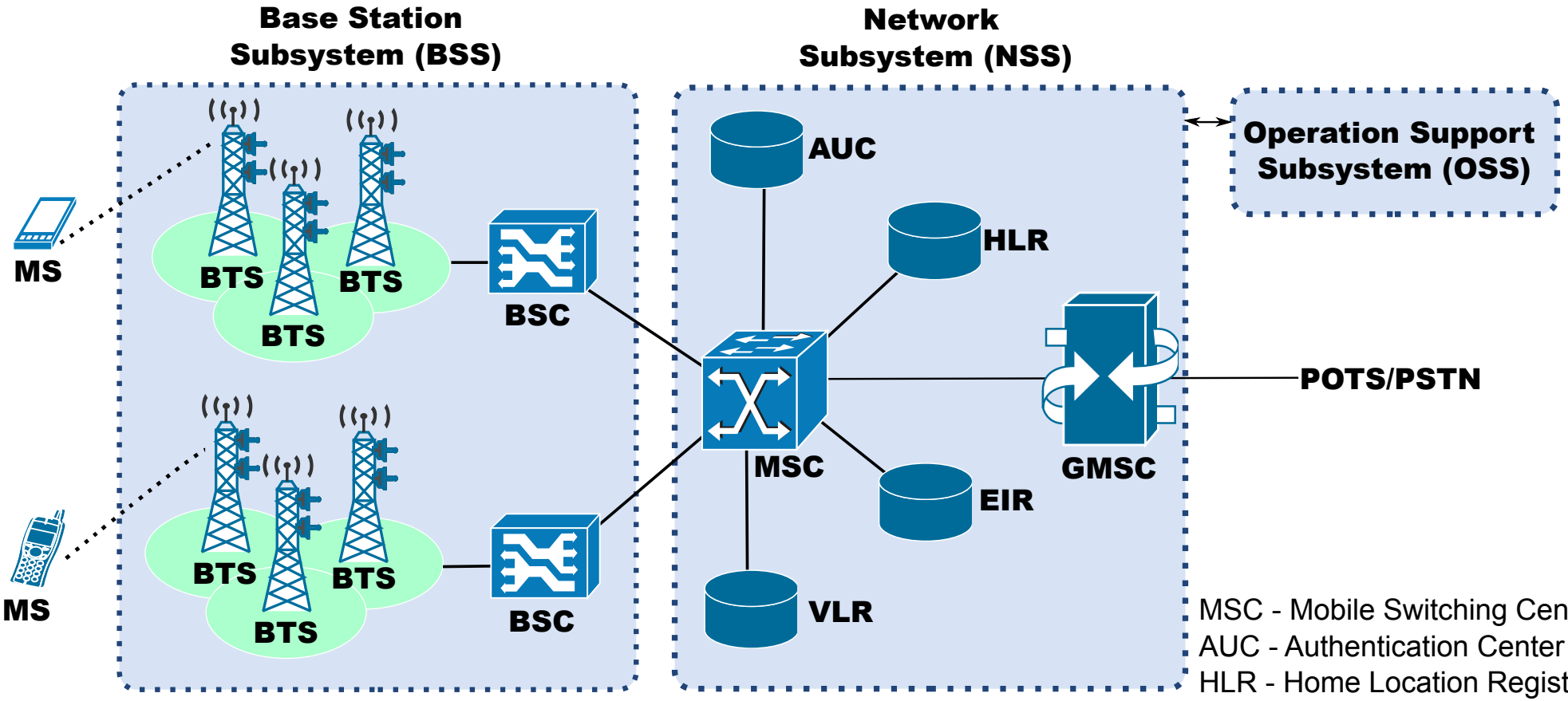


Cellular Network Concept

- Concept used on Public Land Mobile Networks (PLNM).
- Network is distributed over land areas called cells.
  - Each served by at least one fixed-location transceiver, known as base station.
- Macrocells are mainly used to provide a widespread coverage area.
- Smaller micro, pico or femtocell structures can be used for high data-rate.
  - Able to sustain high speed data-traffic by reducing the propagation distance, hence reducing the transmission power.
  - Micro/picocells can handle many devices within the range of a few hundred meters while femtocells are mostly used for indoor or home area.



Global System for Mobile (GSM)

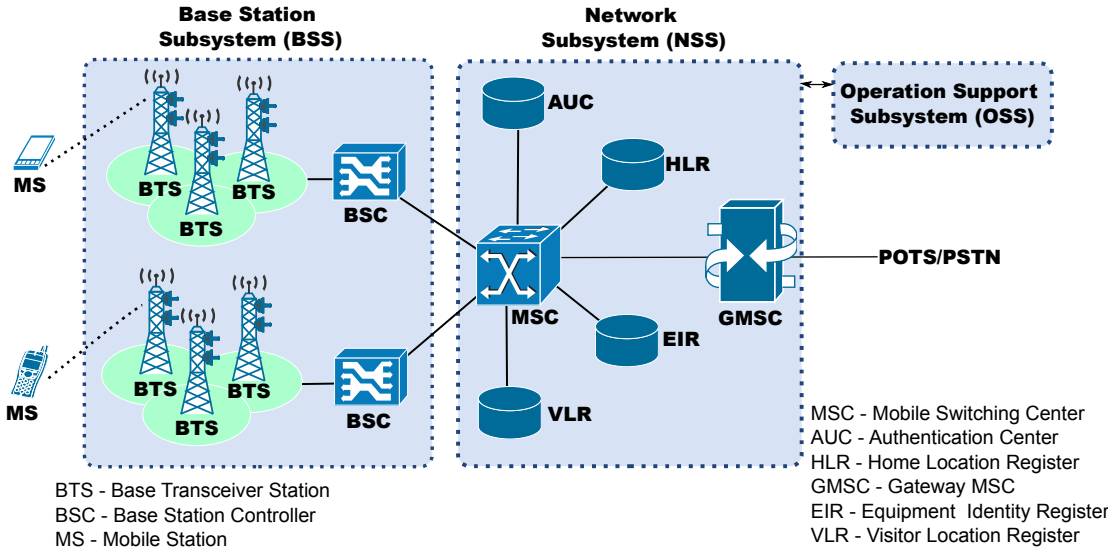


BTS - Base Transceiver Station
BSC - Base Station Controller
MS - Mobile Station

MSC - Mobile Switching Center
AUC - Authentication Center
HLR - Home Location Register
GMSC - Gateway MSC
EIR - Equipment Identity Register
VLR - Visitor Location Register

GSM Network Elements (1)

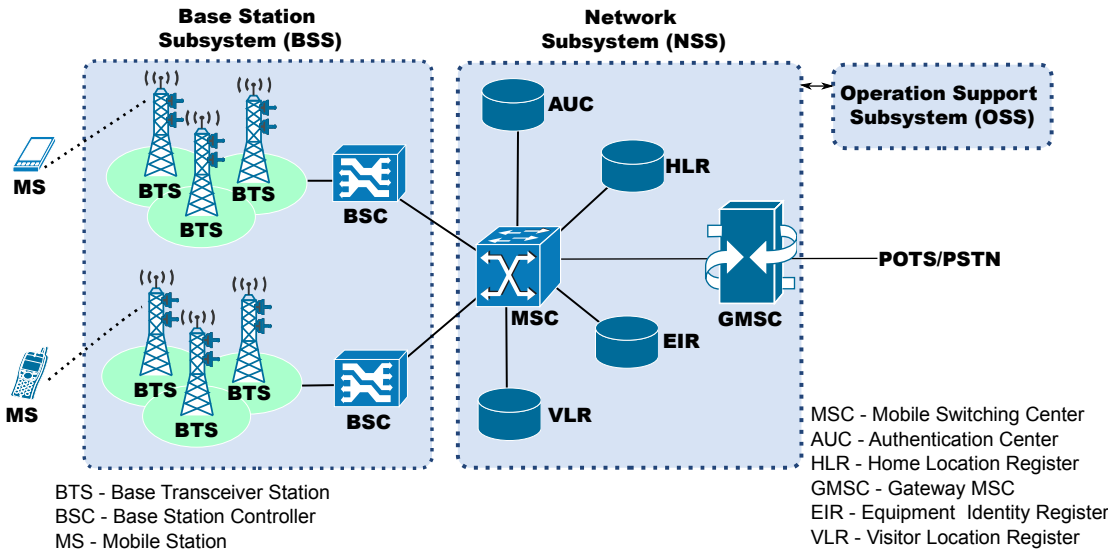
- **Base Station Subsystem (BSS)**
  - Associated with communicating with the mobiles on the network.
  - Base Transceiver Station (BTS)
    - Comprises the radio transmitter receivers, and associated antennas. The BTS is the defining element for each cell.
  - Base Station Controller (BSC)
    - Controls a group of BTSs, and is often co-located with one of the BTSs in its group. It manages the radio resources and controls items such as handover within the group of BTSs and allocates channels.



- **Operation and Support Subsystem (OSS)**
  - Is an element within the overall GSM network architecture that is connected to components of the NSS and the BSC. It is used to control and monitor the overall GSM network and it is also used to control the traffic load of the BSS.

GSM Network Elements (2)

- **Network Switching Subsystem (NSS)**
  - Mobile Switching services Centre (MSC)
    - The main element within the core network area of the overall GSM network architecture.
    - Switching node that provides registration, authentication, call location, inter-MSC handovers and call routing to a mobile subscriber.
    - It also provides an interface to the PSTN.



  - Home Location Register (HLR)
    - Database containing all administrative information about each subscriber along with their last known location.
  - Visitor Location Register (VLR)
    - Contains selected information from the HLR that enables the selected services for the individual subscriber to be provided.
  - Equipment Identity Register (EIR)
    - Decides whether a given mobile equipment may be allowed onto the network. The decision is based on the phone's IMEI.
  - Authentication Centre (AUC)
    - Protected database that contains the secret key also contained in the user's SIM card. Used for authentication and for ciphering on the radio channel.
  - Gateway Mobile Switching Centre (GMSC)
    - Special MSC that acts as a gateway between the GSM network and PSTN.

GSM Air Interface & Physical Channels

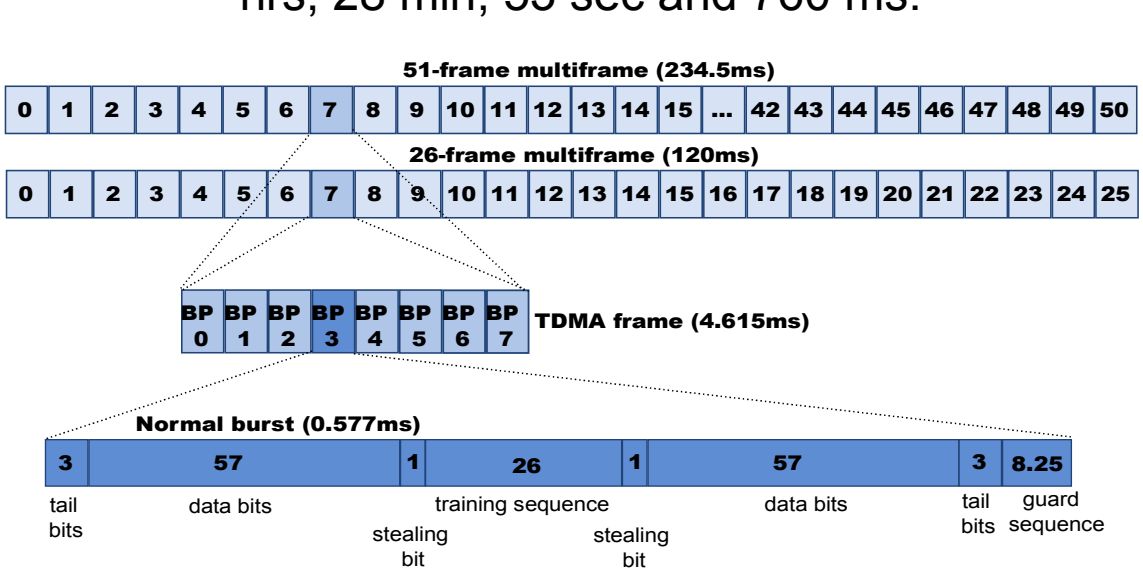
- GSM uses number of channels to carry data over the air Interface, these channels are broadly divided in to following two categories: **Physical Channels** and **Logical Channels**.
- Physical Channels
  - The access method in GSM is both FDMA and TDMA.
  - FDMA (Frequency Division Multiple Access)
    - Achieved by dividing the available radio spectrum into 124 sub-channels each of 200KHz bandwidth so that multiple users can access the system at the same time.
    - 124 channels for downlink (935-960 MHz) and 124 channels for uplink (890-915 MHz).
  - TDMA (Time Division Multiple Access)
    - Each carrier is divided into 8 Time Slots so that each frequency Channel is shared by 8 users at a time on time sharing basis - Physical Channel.
    - The basic radio resource is a time slot with duration of 0.57ms.
    - 8 Time slots of 0.577ms constitutes a 4.615ms TDMA Frame.

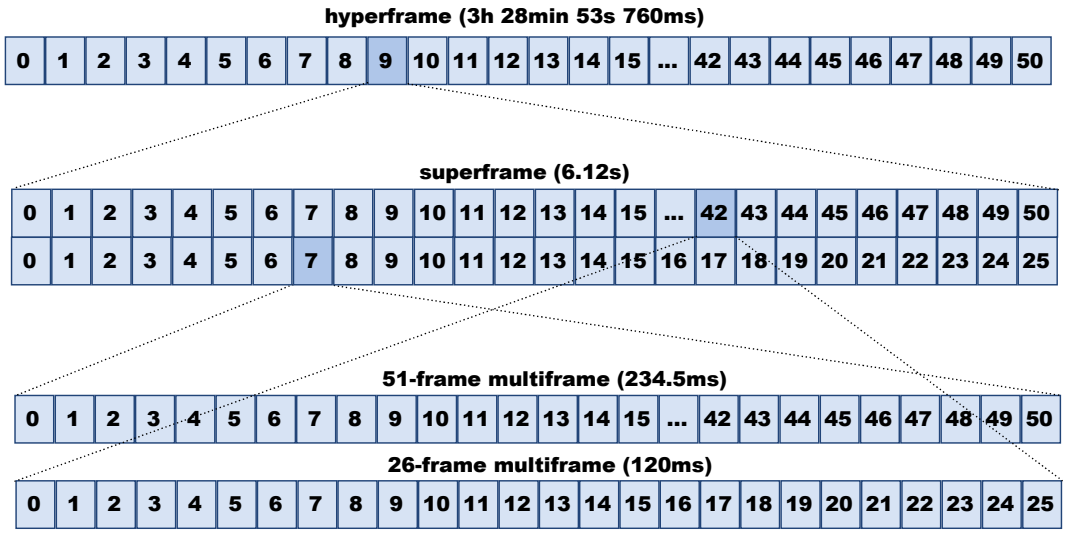
GSM Logical Channels

- Determined by the information carried within the physical channel.
- Used to carry data and signaling information.
- Divided in to following two categories:
  - Traffic Channels.
    - Full Rate Traffic Channels (TCHF): This channel carries information at rate of 22.8 Kbps.
    - Half Rate Traffic Channels (TCHH): This channels carries information at rate of 11.4 Kbps.
  - Signaling Channels.
    - BROADCAST CHANNELS (BCH)
      - Broadcast Control Channel (BCCH) - Broadcasts Network information, e.g. for describing the current control channel structure. The BCCH is a point-to-multipoint channel (BSS-to-MS).
      - Frequency Correction Channel (FCCH) - MS frequency correction.
      - Synchronization Channel (SCH) - Synchronization of the MSs.
    - COMMON CONTROL CHANNELS (CCCH)
      - Random Access Channel (RACH) - MS access requests, response to call announcement, location update, etc.
      - Paging Channel (PCH) - MS terminating call announcement.
    - DEDICATED CONTROL CHANNELS (DCCH)
      - Stand-alone Dedicated Control Channel (SDCCH) - For signaling exchanges, e.g. during call setup, registration / location updates.
      - Slow Associated Control Channel (SACCH) - SDCCH in-band signaling, e.g. for link monitoring.

GSM Frames

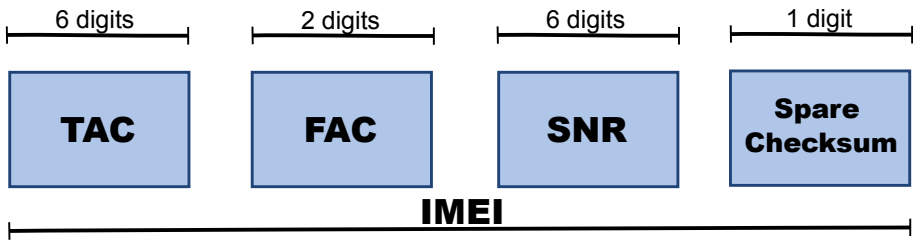
- TDMA frames are grouped together to form multiframes to establish a time schedule for operation.
- There are two types of multiframes in the system:
  - 26 TDMA (Traffic) Multiframe: Consists 26 TDMA frames with duration of 120 ms and used to carry the Logical Channels TCHF, TCHH, SACCH (frame 12 or 25), etc.
  - 51 TDMA (Control) Multiframe: Consists 51 TDMA frames with duration of 234.5 ms and used to carry the Logical Channels FCCH, SCH, BCCH, CCCH, SDCCH, SACCH etc.
- Multiframes further structured in to Superframe and Hyperframe:
  - Superframe consists of 51x26 TDMA frames with duration of 6.12 sec.
  - Hyperframe consists 2048 superframes (2048x51x26 TDMA frames) with duration of 3 hrs, 28 min, 53 sec and 760 ms.

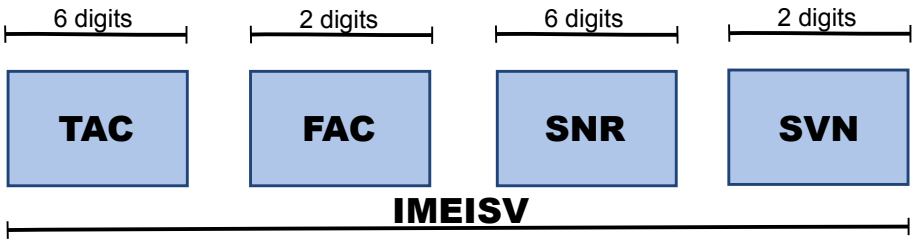


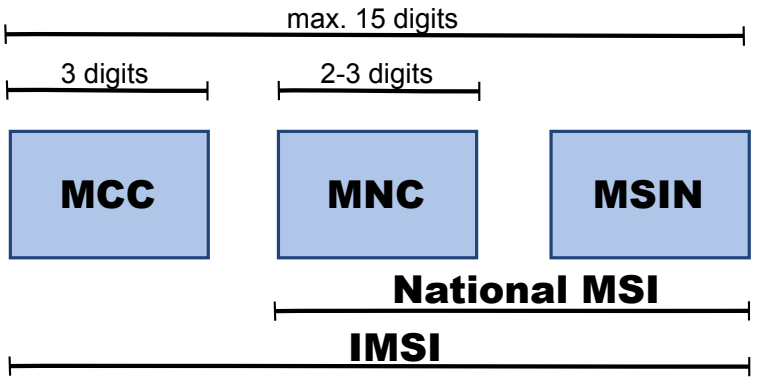


GSM Addresses and Identifiers (1)

- **International Mobile Station Equipment Identity (IMEI)**
  - Allocated by the equipment manufacturer and registered by the network operator, who stores it in the EIR.
  - Allows to recognize of obsolete, stolen, or non-functional equipments.
  - IMEI is composed by 15-digits: Type Approval Code (TAC) 8 digits, centrally assigned; Serial Number (SNR) 6 digits, assigned by the manufacturer; Spare or Checksum 1 digit.
  - IMEISV (IMEI Software Version) is composed by 16-digits: TAC 8 digits; SNR 6 digits: 2 digits for software version (SVN).
- **International Mobile Subscriber Identity (IMSI)**
  - Every registered user has an IMSI with a valid IMEI stored in their SIM.
  - Composed by Mobile Country Code (MCC) 3 digits, internationally standardized; Mobile Network Code (MNC) 2-3 digits, for unique identification of mobile network within the country; Mobile Subscriber Identification Number (MSIN) maximum 10 digits, identification number of the subscriber in the home mobile network.





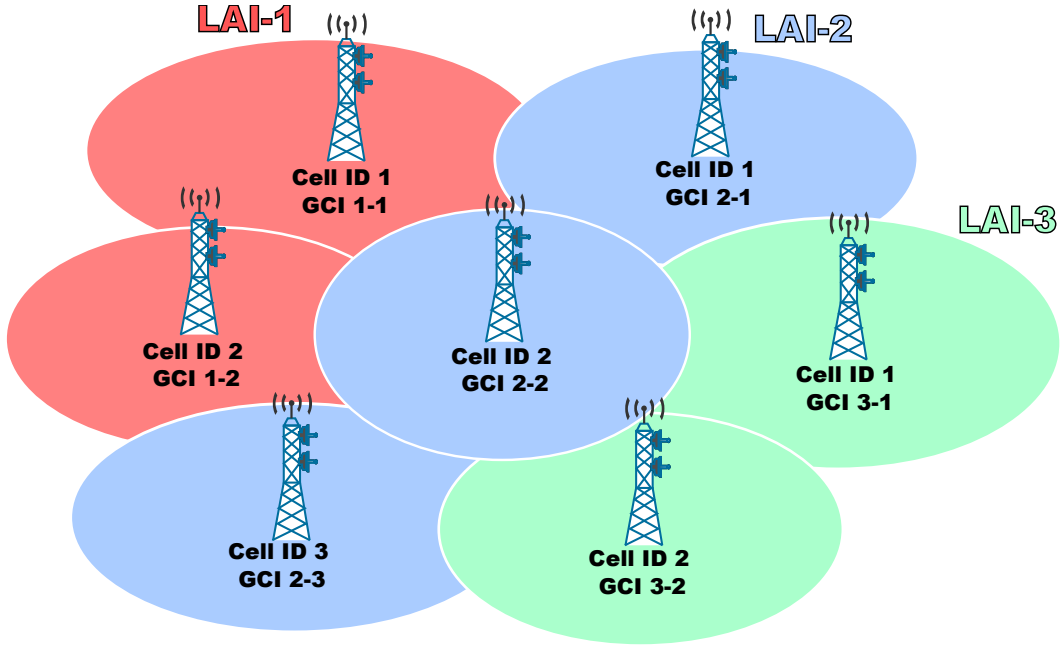


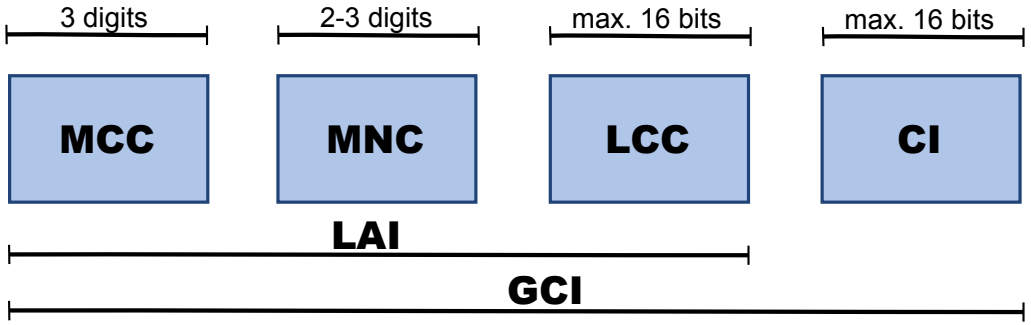
GSM Addresses and Identifiers (2)

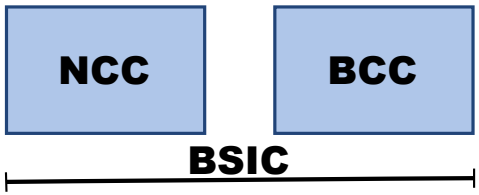
- **Mobile Subscriber ISDN Number (MSISDN)**
  - Is the user's telephone number.
  - Composed by Country Code (CC) up to 3 digits; National Destination Code (NDC) typically 2-3 digits; Subscriber Number (SN) maximum 10 digits.
- **Mobile Station Roaming Number (MSRN)**
  - Interim location dependent number, assigned to a mobile station by a regionally responsible VLA.
  - Used to route telephone calls in a mobile network from a GMSC to the target MSC.
  - Same format as MSISDN.
- **Temporary Mobile Subscriber Identity (TMSI)**
  - Assigned by the VLR, which is responsible for the current location of a subscriber.
  - Have only local significance in the area handled by the VLR.
  - Stored on the network side only.

GSM Addresses and Identifiers (3)

- **Location Area Identity (LAI)**
  - Identifies, within a PLMN, a group of cells (location Area - LA).
  - Hierarchy is based on international standard and structured in a unique format as mentioned below:
    - Mobile Country Code (MCC) 3 digits; Mobile Network Code (MNC) 2-3 digits; Location Area Code (LAC) maximum 5 digits or maximum 16 bits coded in hexadecimal.
- **Cell Identifier (CI)**
  - Identifies individual cells within an LA. Maximum 16 bits.
- **Global Cell Identity (GCI)**
  - Is the combination of LAI and CI.
- **Base Station Identity Code (BSIC)**
  - Identity of BS that allows to differentiate cells with the same frequencies.
  - Composed of Network Colour Code (NCC) and Base Station Colour Code (BCC).







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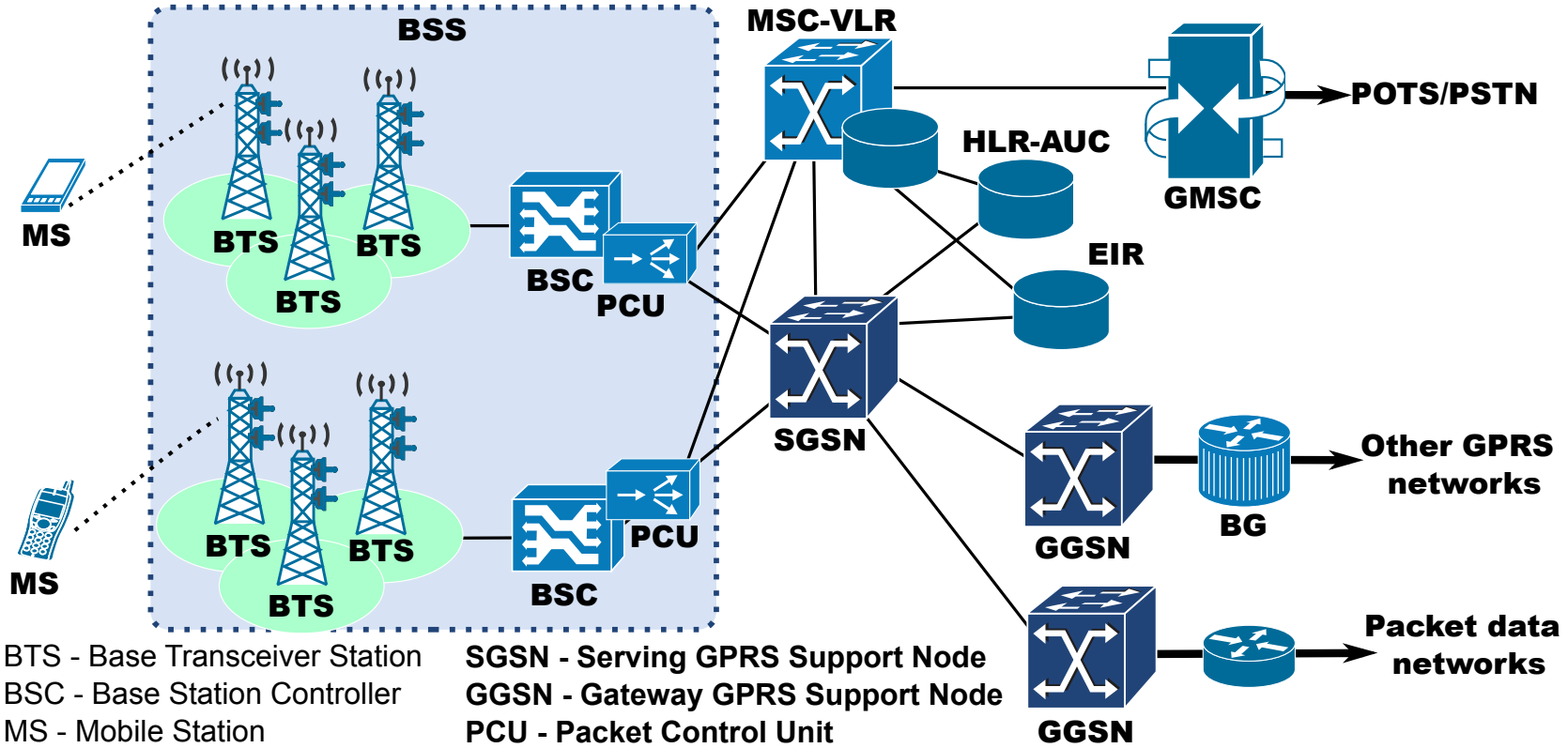
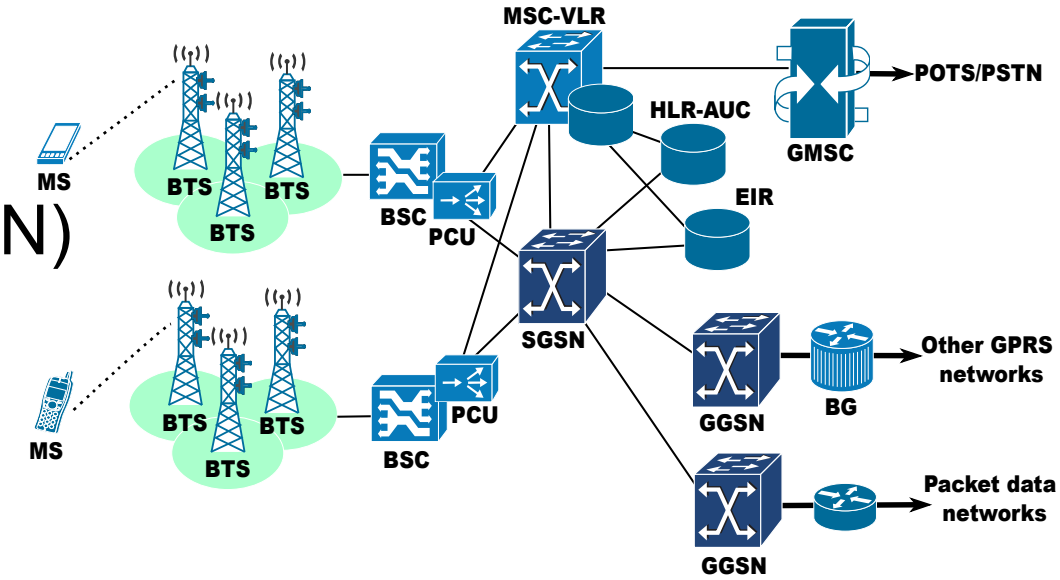
GSM Packet Radio System (GPRS)



BTS - Base Transceiver Station
BSC - Base Station Controller
MS - Mobile Station

SGSN - Serving GPRS Support Node
GGSN - Gateway GPRS Support Node
PCU - Packet Control Unit
BG - Border Gateway
MSC - Mobile Switching Center
AUC - Authentication Center
HLR - Home Location Register
GMSC - Gateway MSC
EIR - Equipment Identity Register
VLR - Visitor Location Register

GPRS Network Elements



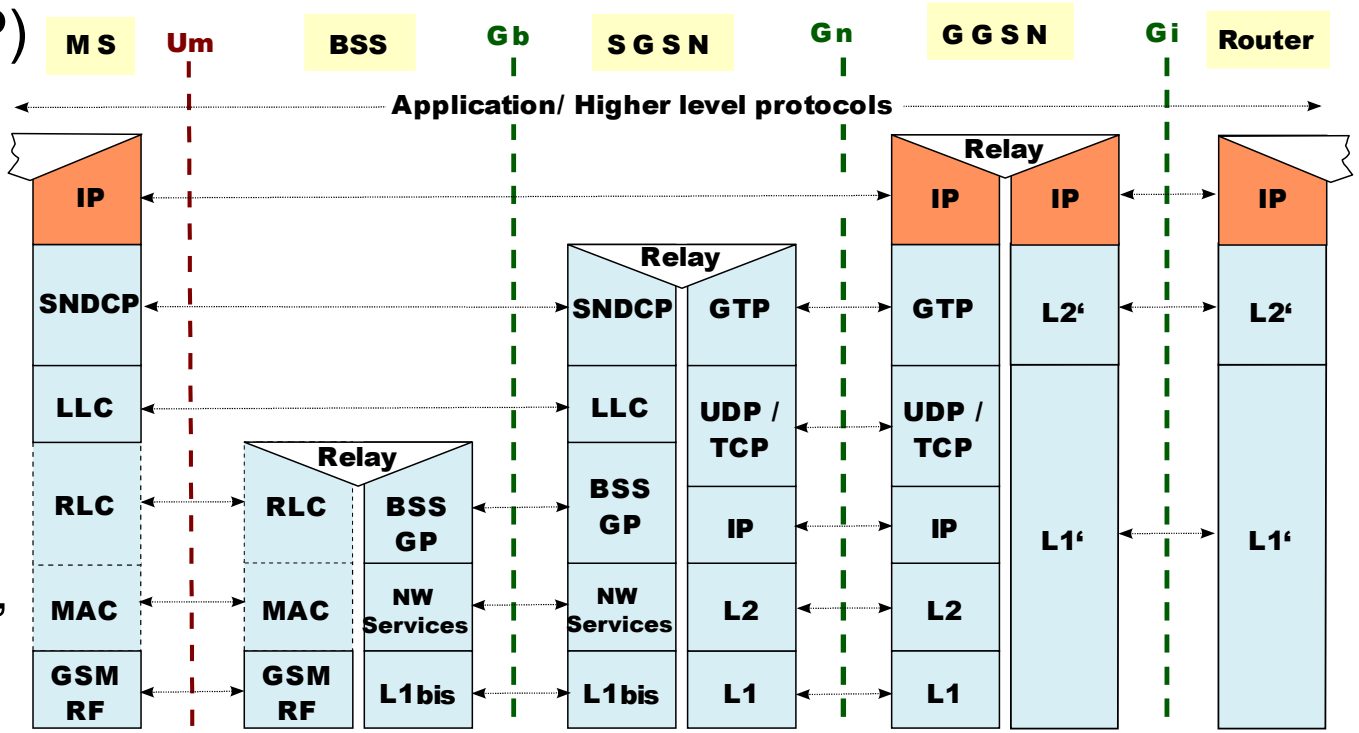
- Serving GPRS Support Node (SGSN)
  - Gateway to the services within the network.
  - Provides a variety of services to the mobiles:
    - Packet routing and transfer, mobility management, attach/detach, logical link management, authentication and charging data.
- Gateway GPRS Support Node, (GGSN)
  - Gateway to external networks (GPRS or Packet Data Networks).
- Packet Control Unit (PCU)
  - Differentiates whether data is to be routed to the packet switched (SGSN) or circuit switched networks (MSN).

GPRS Network Interfaces

- **Um** (Between MS and BSS, and between MS and SGSN)
  - Used between MS and BSS/SGSN for exchange of user and signaling information.
- **Gb** (Between SGSN and BSS)
  - Used between SGSN and BSS for data transfer and mobility management.
- **Gn** (Between SGSN and GGSN)
  - Used to support mobility, applicable when GGSN and SGSN are located in same PLMN.
- **Gi** (Between GGSN and Packet Data Network)
  - Used to exchange data with external packet data network.
- **Gp** (Between SGSN and GGSN)
  - Used to support mobility, applicable when GGSN and SGSN are located in different PLMNs.
- **Gr** (Between SGSN and HLR)
  - Used by the SGSN to obtain subscriber information from HLR.
- **Gf** (Between SGSN and EIR)
  - Used by SGSN to enable EIR to verify the IMEI retrieved from MS (optional).
- **Gs** (Between SGSN and VLR)
  - Used for coordinating the functions of SGSN and VLR when and Mobile has both GSM and GPRS services (optional).

GPRS User Plane

- GPRS Tunneling protocol (GTP)
  - Encapsulates user data when passing through core network.
- Subnetwork Dependent Convergence Protocol (SNDCP)
  - Compression, Segmentation/Concatenation, and Multiplexing.
- Logical Link Control (LLC)
  - Data transfer to different MS, provides data transport for different Layer-3 sublevels, provides one or more logical links to 1 MS, sequence control, error protection/correction , data flow control, and ciphering.
- Radio Link Control/Media Access Control (RLC/MAC)
  - Block coding, Forward Error Correction (FEC), interleaving, congestion control on air interface, synchronization, timing advance, signal quality estimation, signal level estimation, transmitting power control, and burst generation.



GPRS Physical Channels

- GPRS uses the existing GSM resources: spectrum, channels (200 kHz), and timeslots.
  - GPRS users will share the same TDMA frame with GSM voice users.
- An RLC/MAC PSU is mapped into the data part of four time slots, one from four consecutive frames, called radio block.
- The radio block is the basic transmission unit of a GPRS Packet Data Channel (PDCH).
  - All GPRS logical traffic and control channel are mapped to a PDCH.
- PDCHs share slots with GSM circuit-switched traffic channels.
  - GPRS air interface will dynamically allocate resources (timeslots) for voice and PDCH.
    - Certain physical channels will be configured for packet data use, but can be re-configured for voice if needed.
- PDCHs are assigned to transmit individual packets, and are released at the conclusion of the transmission.
- PDCHs are further defined in terms of a 52-frame multiframe.

GPRS Logical Channels (1)

- Broadcast channels
  - Packet Broadcast Central Channel (PBCCH)
    - Downlink only channel that is used to broadcast information to mobiles and informs them of incoming calls. Very similar in operation to the BCCH used for GSM.
- Common control channels
  - Packet Paging Channel (PPCH)
    - Downlink only channel, used to alert the mobile to an incoming call and to alert it to be ready to receive data.
    - Used for control signaling prior to the call set up. Once the call is in progress a dedicated channel referred to as the PACCH takes over.
  - Packet Access Grant Channel (PAGCH)
    - Downlink channel, used to send information notifying the mobile which traffic channel has been assigned to it.
  - Packet Notification Channel (PNCH)
    - Downlink only channel, used to alert mobiles that there is broadcast traffic intended for a large number of mobiles.
    - Typically used in what is termed point-to-point multicasting.
  - Packet Random Access Channel (PRACH)
    - Uplink channel that enables the mobile to initiate a burst of data in the uplink.

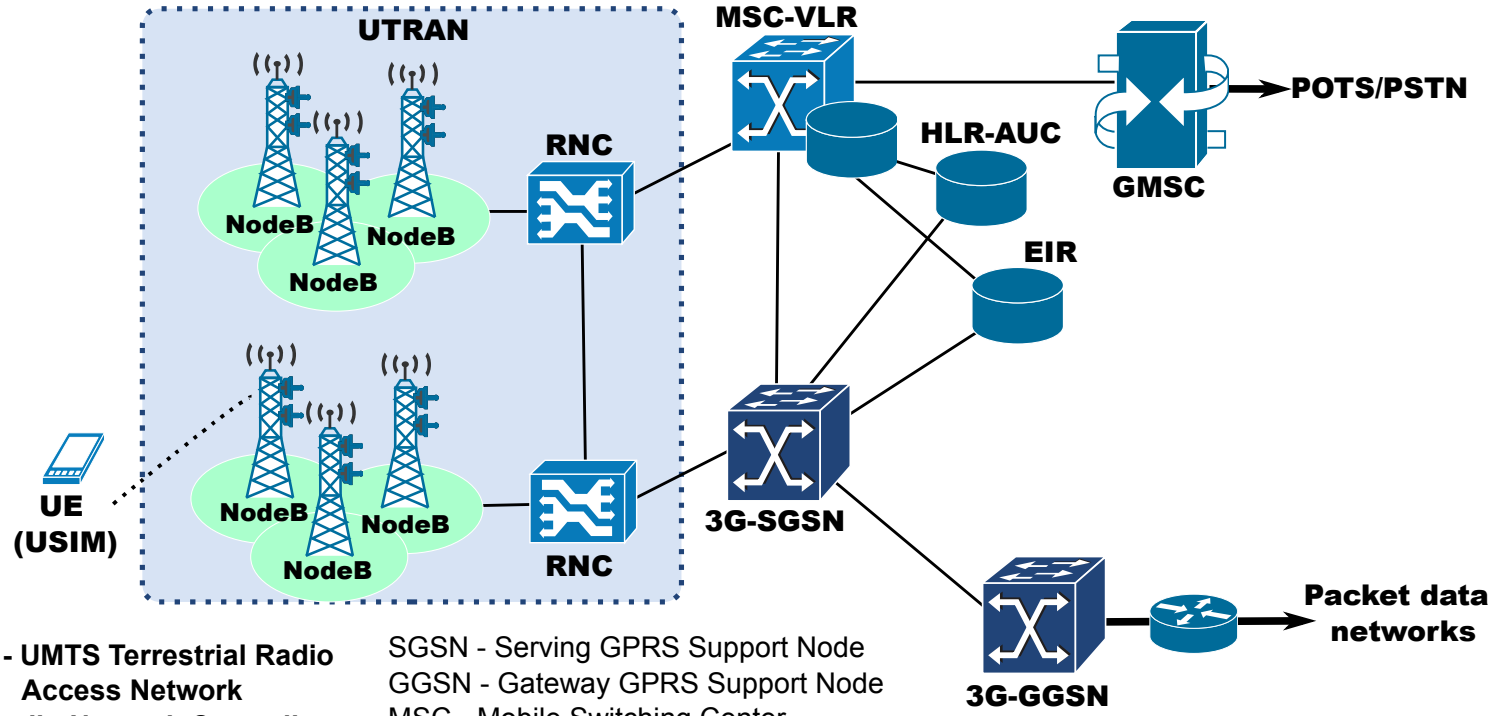
GPRS Logical Channels (2)

- Dedicated control channels
  - Packet Associated Control Channel (PACCH)
    - Present in both uplink and downlink directions, used for control signaling while a call is in progress.
  - Packet Timing Advance Common Control Channel (PTCCH)
    - Present in both the uplink and downlink directions, used to adjust the timing advance.
    - This is required to ensure that messages arrive at the correct time at the base station regardless of the distance of the mobile from the base station.
- Dedicated traffic channel
  - Packet Data Traffic Channel (PDTCH)
    - Present in both the uplink and downlink directions, used to send the traffic.

Enhanced Data-rates for GSM Evolution (EDGE)

- The next advance in GSM radio access technology was EDGE (Enhanced Data rates for Global Evolution) or Enhanced GRPS.
  - New modulation technique yielding a three-fold increase in bit rate (8PSK replacing GMSK) .
  - New channel coding for spectral efficiency.
- EDGE was successfully introduced without disrupting the frequency re-use plans of existing GSM deployments.
- Increase in data speeds to 384Kbps (theoretical).

Universal Mobile Telecommunication System (UMTS)



UTRAN - UMTS Terrestrial Radio Access Network
RNC - Radio Network Controller
UE - User Equipment
USIM - UMTS Subscriber Identity Module

SGSN - Serving GPRS Support Node
GGSN - Gateway GPRS Support Node
MSC - Mobile Switching Center
AUC - Authentication Center
HLR - Home Location Register
GMSC - Gateway MSC
EIR - Equipment Identity Register
VLR - Visitor Location Register

- 3rd Generation Partnership Project (3GPP) standard.
- Novel radio access network called Universal Terrestrial Radio Access Network (UTRAN)
- Core network remains largely unchanged from GPRS/EDGE.

UMTS Air Interfaces

- There are two methods of providing duplex for UMTS.
  - Frequency Division Duplex (FDD).
    - Uses two channels spaced sufficiently apart so that the receiver can receive while the transmitter is also operating.
    - Time Division Duplex (TDD) where short time blocks are allocated to transmissions in both directions.
- UMTS has different terrestrial air interfaces:
  - Wideband Code Division Multiple Access (W-CDMA) for UMTS-FDD
  - Time-Division-Code Division Multiple Access (TD-CDMA) for UMTS-TDD.
  - Time-Division-Synchronous Code Division Multiple Access (TD-SCDMA) for UMTS-TDD.
- Universal Terrestrial Radio Access Network (UTRAN)
  - NodeB
    - Responsible for radio transmission/reception in one or more cells to/from the UE.
    - Interacts with the RNC.
  - Radio Network Controller (RNC)
    - Controls the use and the integrity of the radio resources.
- Data carried by the UMTS / W-CDMA transmissions is organized into frames, slots and channels.

UMTS Physical Channels

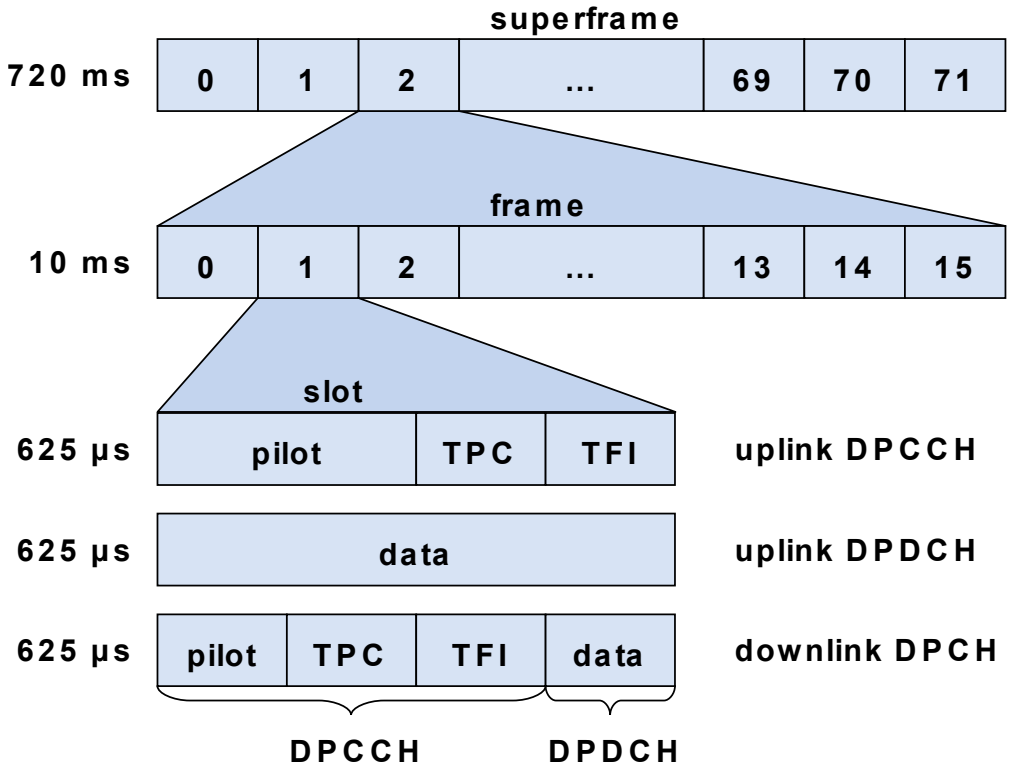
- Primary Common Control Physical Channel (PCCPCH) (downlink).
  - Continuously broadcasts system identification and access control information.
- Secondary Common Control Physical Channel (SCCPCH) (downlink)
  - Carries the Forward Access Channel (FACH) providing control information, and the Paging Channel (PACH) with messages for UEs that are registered on the network.
- Physical Random Access Channel (PRACH) (uplink).
  - This channel enables the UE to transmit random access bursts in an attempt to access a network.
- Dedicated Physical Data Channel (DPDCH) (up and downlink).
  - Used to transfer user data.
- Dedicated Physical Control Channel (DPCCH) (up and downlink).
  - Carries control information to and from the UE. In both directions the channel carries pilot bits and the Transport Format Combination Identifier (TFCI).
- Physical Downlink Shared Channel (PDSCH) (downlink).
  - Shares control information to UEs within the coverage area of the node B.
- Physical Common Packet Channel (PCPCH)
  - Specifically intended to carry packet data.
- Synchronization Channel (SCH)
- Common Pilot Channel (CPICH)
  - Transmitted by every node B so that the UEs are able estimate the timing for signal demodulation.
- Acquisition Indicator Channel (AICH)
  - Used to inform a UE about the Data Channel (DCH) it can use to communicate with the node B.
- Paging Indication Channel (PICH)
  - Provides the information to the UE to be able to operate its sleep mode to conserve its battery when listening on the Paging Channel (PCH).
- CPCH Status Indication Channel (CSICH) (downlink)
  - Carries the status of the CPCH and may also be used to carry some intermittent, or "bursty" data.
- Collision Detection/Channel Assignment Indication Channel (CD/CA-ICH) (downlink)
  - Indicates whether the channel assignment is active or inactive to the UE.

UMTS Transport & Logical Channels

- Transport
  - Dedicated Transport Channel (DCH) (up and downlinks).
    - Used to transfer data to a particular UE. Each UE has its own DCH in each direction.
  - Broadcast Channel (BCH) (downlink).
    - Broadcasts information to the UEs in the cell to enable them to identify the network and the cell.
  - Forward Access Channel (FACH) (downlink).
    - Carries data or information to the UEs that are registered on the system.
  - Paging Channel (PCH) (downlink).
    - Carries messages that alert the UE to incoming calls, SMS messages, data sessions or required maintenance such as re-registration.
  - Random Access Channel (RACH) (uplink).
    - Carries requests for service from UEs trying to access the system.
  - Uplink Common Packet Channel (CPCH) (uplink).
    - Provides additional capability beyond that of the RACH and for fast power control.
  - Downlink Shared Channel (DSCH) (downlink).
    - Shared by several users and is used for data that is "bursty" in nature.
- Logical
  - Broadcast Control Channel (BCCH) (downlink).
    - Broadcasts information to UEs relevant to the cell.
  - Paging Control Channel (PCCH) (downlink).
    - Associated with the PICH and used for paging messages and notification information.
  - Dedicated Control Channel (DCCH) (up and downlinks)
    - Used to carry dedicated control information in both directions.
  - Common Control Channel (CCCH) (up and downlinks).
    - Used to transfer control information.
  - Shared Channel Control Channel (SHCCH) (up and downlinks).
    - Used to transport shared channel control information.
  - Dedicated Traffic Channel (DTCH) (up and downlinks).
    - Used to carry user data or traffic.
  - Common Traffic Channel (CTCH) (downlink)
    - Used to transfer dedicated user information to a group of UEs.

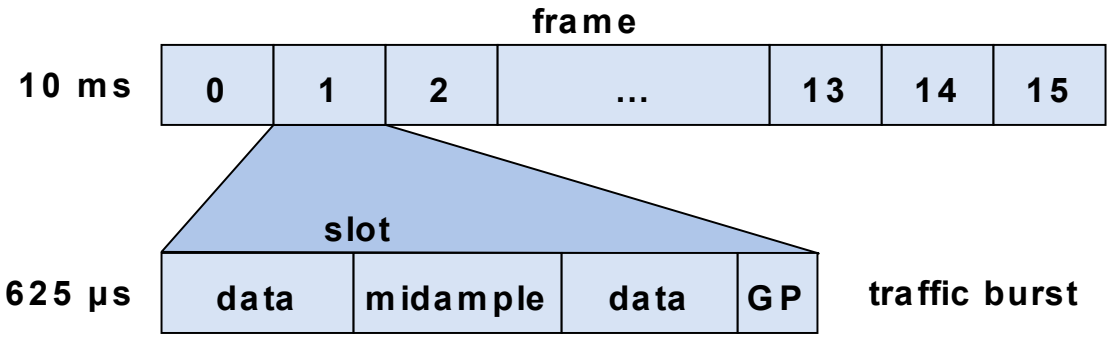
UMTS Frames

- UMTS-FDD



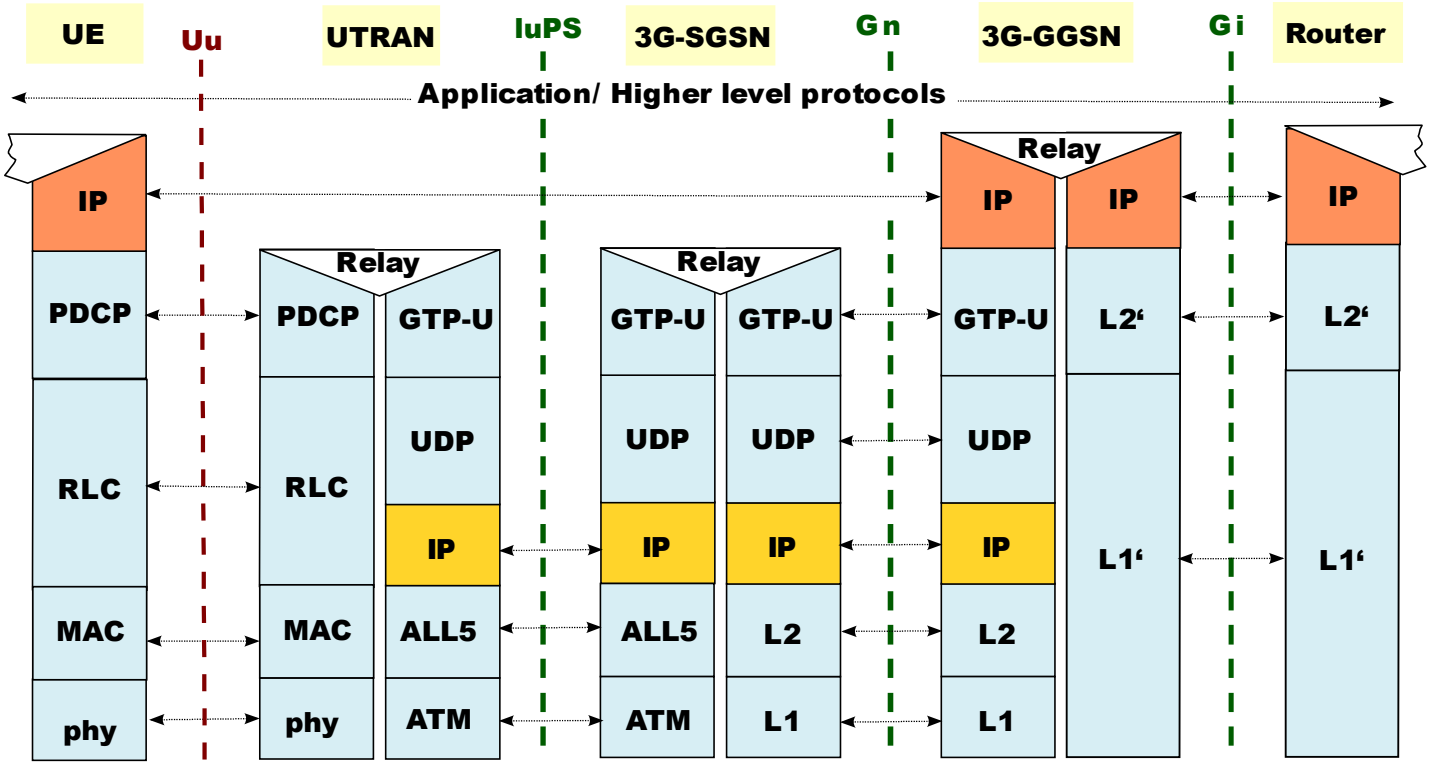
TPC: Transmit Power Control
TFI: Transport Format Identifier
DPCCH: Dedicated Physical Control Channel
DPDCH: Dedicated Physical Data Channel
DPCH: Dedicated Physical Channel

- UMTS-TDD



GP: Guard Period

UMTS User Plane



- Packet Data Convergence Protocol (PDCP)
  - Header compression and decompression, transfer of data, integrity protection and integrity verification, and Ciphering and deciphering.
- GTP-U is the transport network protocol.
- Migration to ATM for Radio Access Transport.

High Speed Packet Access (HSPA)

- Upgrade to W-CDMA networks to provide **higher bit rates** and **lower delays**.
- High-Speed Downlink Packet Access (HSDPA)
  - To be able to make faster decisions on radio channel allocation (adapting to varying channel quality) and reduces delays, new functions were added closer to the radio interface (NodeB):
    - Scheduling, select which UE(s) is/are to use the radio resources at each Transmission Time Interval (TTI), where one TTI is 2 ms.
    - Link adaptation, setting of channel coding rate and modulation (QPSK or 16QAM), in order to utilize the resources effectively.
- High-Speed Uplink Packet Access (HSUPA)
  - Uses a packet scheduler that operates on a request-grant principle where the UEs request a permission to send data and the scheduler decides when and how many UEs will be allowed to do so.
  - However, unlike HSDPA, uplink transmissions are not orthogonal to each other.
- Evolved High Speed Packet Access (HSPA+)
  - Further increase bit rates.
  - New functions are added:
    - Higher order modulation 64QAM (DL) and 16QAM (UL),
    - Multiple Input Multiple Output (MIMO) used only in the DL.

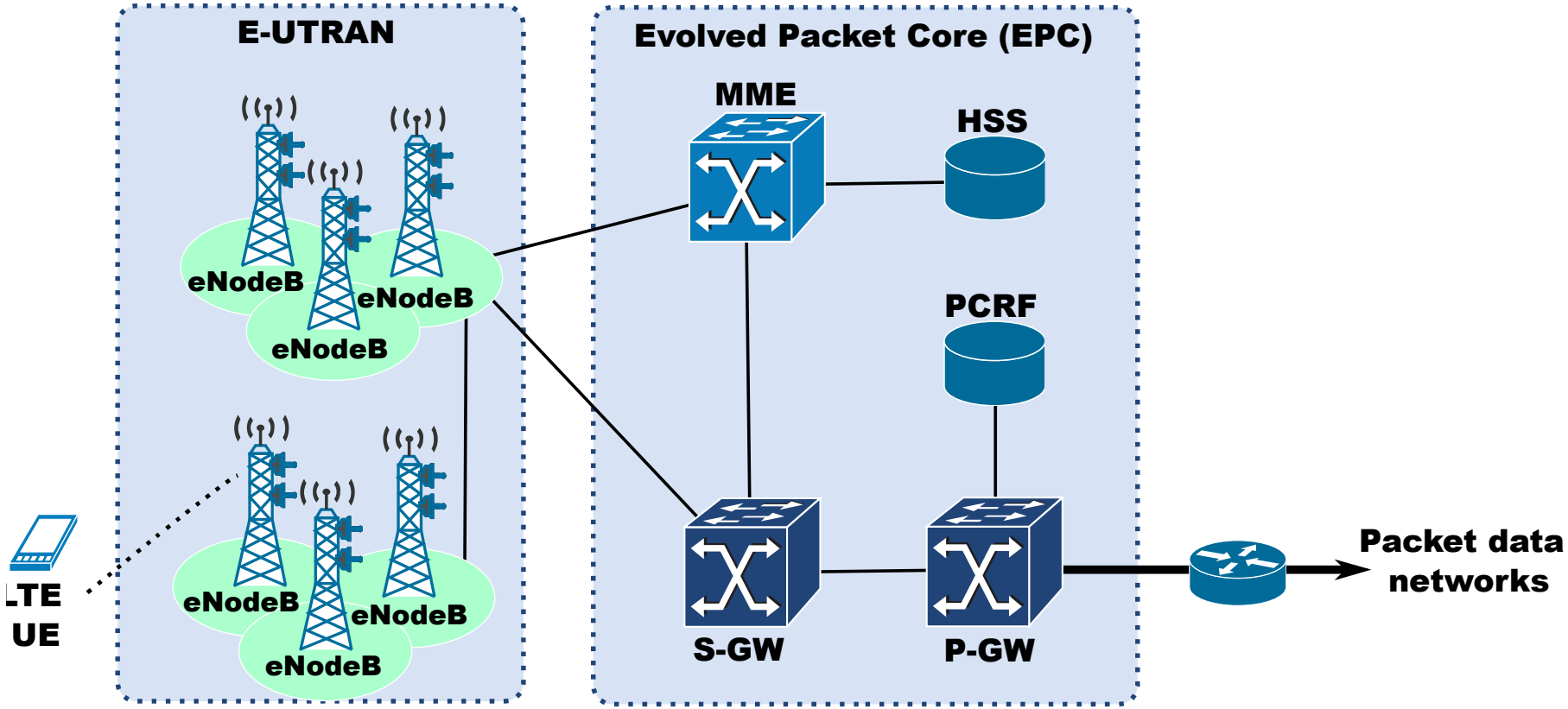
CDMA2000 and 1xEV-DO

- CDMA2000 is a family of standards proposed by 3rd Generation Partnership Project 2 (3GPP2) standard.
  - Concurrent to 3GPP UMTS.
- CDMA2000 Evolution-Data Optimized (1xEV-DO or EVDO) evolved from CDMA2000.
  - Standardized by 3GPP2.
  - Packet data only network
    - Voice is carried either by using VoIP, or by using a fall-back to a CDMA2000 carrier.
  - Forward channel forms a dedicated variable-rate, packet data channel with signaling and control time multiplexed into it.
    - The channel is itself time-divided and allocated to each user on a demand and opportunity driven basis.
    - A data only format was adopted to enable the standard to be optimized for data applications.

Long Term Evolution (LTE)

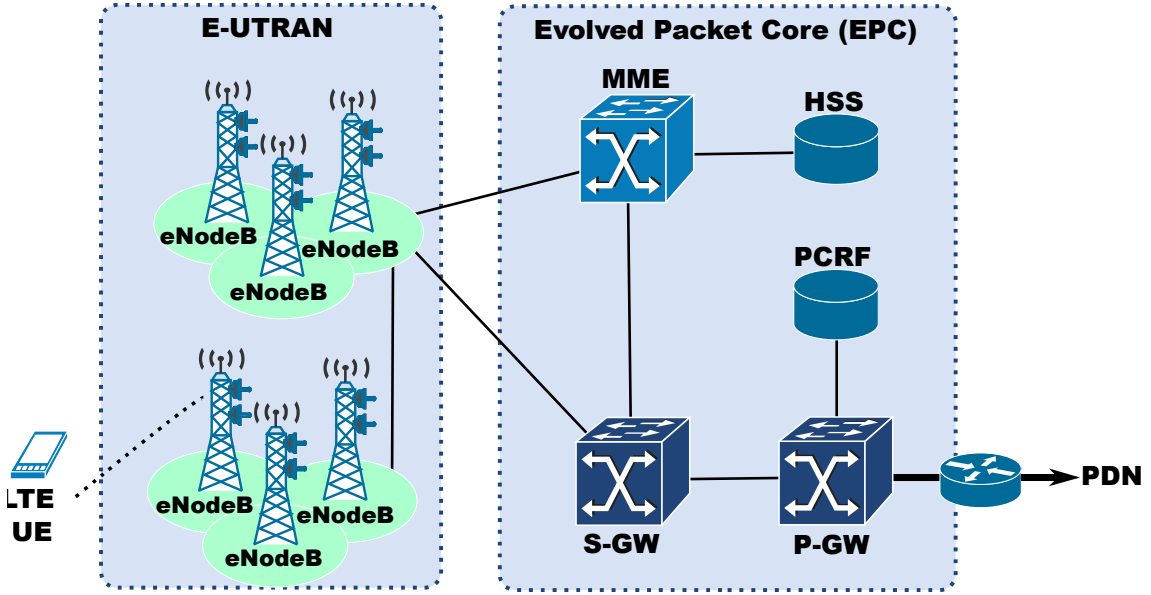
- LTE standard has been developed by 3GPP
  - Extension of UMTS (based on 3GPP standard)
  - and CDMA200 1xEV-DO (based on 3GPP2 standard).
- Designed for high speed data applications both in the uplink and downlink.
  - Offers about 300Mbps data rate in the downlink and about 75 Mbps in the uplink.
- LTE is an all IP based network, supporting both IPv4 and IPv6.
  - Possibility of supporting voice over LTE (VoLTE).
- Uses a different form of radio interface from UMTS.
  - Instead of CDMA it uses OFDMA (Orthogonal Frequency Division Multiple Access is used in the downlink; and SC-FDMA(Single Carrier - Frequency Division Multiple Access) is used in the uplink.
- Uses MIMO (Multiple Input Multiple Output).
  - Requires the use of multiple antennas (antenna matrices).
- LTE has been defined to accommodate both FDD and TDD operation.

Long Term Evolution (LTE)



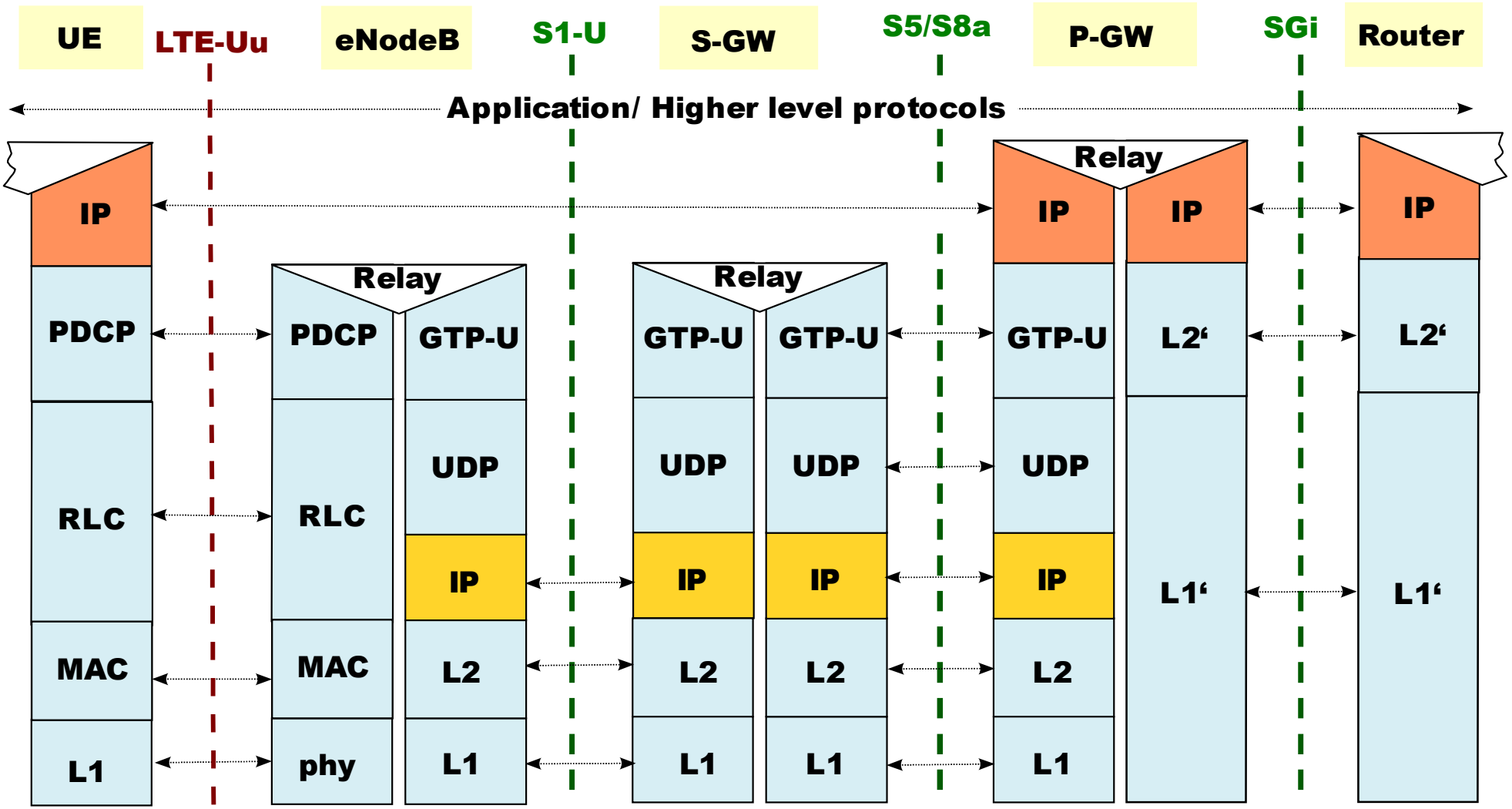
S-GW - Serving Gateway
P-GW - Packet data network Gateway
MME - Mobility Management Entity
HSS - Home Subscriber Server
PCRF - Policy and Charging Rules Function

LTE Components



- E-UTRAN
  - eNodeB
    - X2 Interface (eNodeb-eNodeB)
- Evolved Packet Core (EPC)
  - Serving Gateway (S-GW)
    - Termination point of the packet data interface towards E-UTRAN.
  - Packet Data Network Gateway (P-GW)
    - Termination point of the packet data interface towards the Packet Data Network (PDN)
  - Mobility Management Entity (MME)
    - Responsible for all the Control plane functions related to subscriber and session management.
    - Provides security procedures, terminal-to-network session handling, and idle terminal location management.
  - Home Subscriber Server (HSS)
    - Merge of UMTS HLR and AUC.
    - Provides user identification and addressing (HLR), user profile information (HLR), mutual network-terminal authentication (AUC), and radio path ciphering and integrity protection (AUC).
  - Policy and Charging Rules Function Server (PCRF)
    - Manages the service policy.

LTE User Plane



LTE Physical Channels

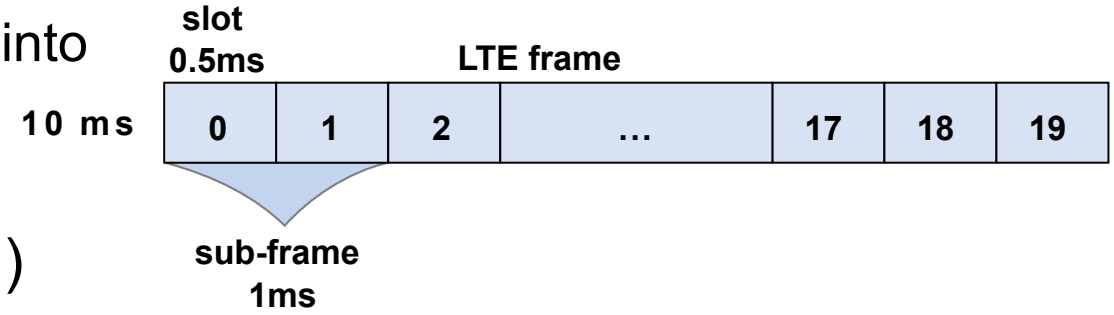
- Physical Broadcast Channel (PBCH) (downlink)
  - Carries system information for UEs requiring to access the network.
- Physical Control Format Indicator Channel (PCFICH) (downlink)
  - Informs the UE about the format of the signal being received.
- Physical Downlink Shared Channel (PDSCH) (downlink)
  - Used to carry high speed data/multimedia information.
- Physical Downlink Control Channel (PDCCH) (downlink)
  - Carries scheduling information of different types: downlink resource scheduling, uplink power control instructions, uplink resource grant, indication for paging or system information.
- Physical Control Format Indicator Channel (PCFICH) (downlink)
  - Provides information about number of symbols used for PDCCH transmission.
- Physical Hybrid ARQ Indicator Channel (PHICH) (downlink)
  - Reports the Hybrid ARQ status.
- Physical Uplink Control Channel (PUCCH) (uplink)
  - Provides the various control signaling requirements.
- Physical Uplink Shared Channel (PUSCH) (uplink)
  - Is the Uplink counterpart of PDSCH.
- Physical Random Access Channel (PRACH) (uplink)
  - Used for random access functions.

LTE Transport & Logical Channels

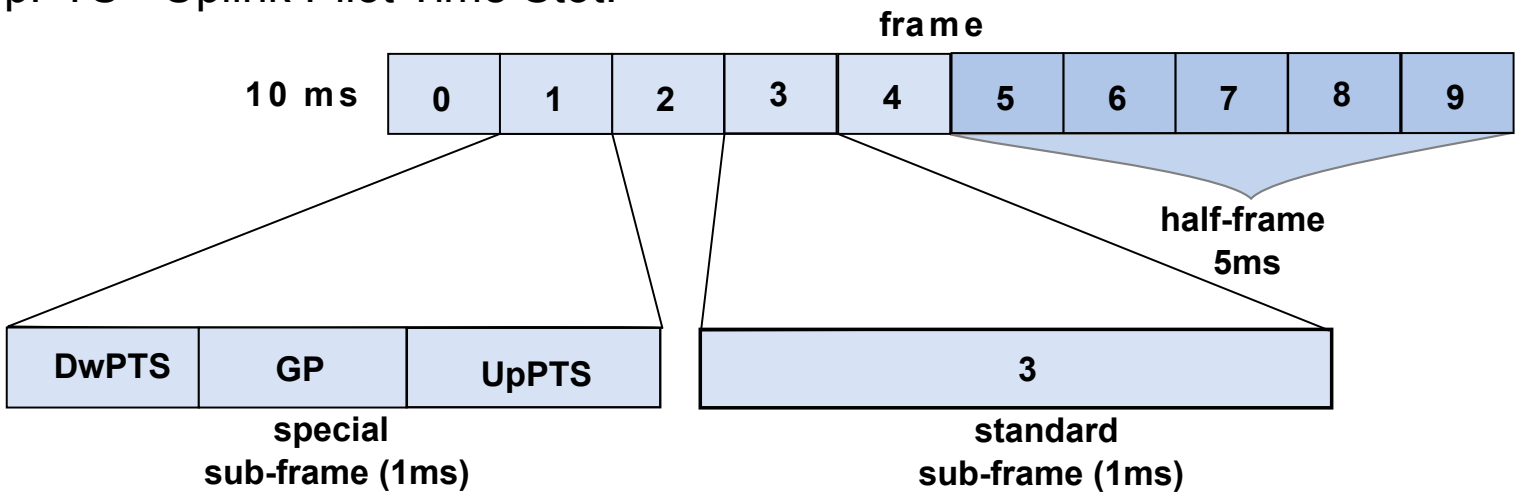
- Transport
  - Broadcast Channel (BCH) (downlink)
    - Maps to Broadcast Control Channel (BCCH).
  - Downlink Shared Channel (DL-SCH)
    - Main channel for downlink data transfer.
  - Paging Channel (PCH) (downlink)
    - To convey the PCCH
  - Multicast Channel (MCH) (downlink)
    - Used to transmit MCCH information to set up multicast transmissions.
  - Uplink Shared Channel (UL-SCH)
    - Main channel for uplink data transfer.
  - Random Access Channel (RACH) (uplink)
    - Used for random access requirements.
- Logical
  - Broadcast Control Channel (BCCH)
    - Provides system information to all mobile terminals connected to the eNodeB.
  - Paging Control Channel (PCCH)
    - Used for paging information when searching a unit on a network.
  - Common Control Channel (CCCH)
    - Used for random access information, e.g. for actions including setting up a connection.
  - Multicast Control Channel (MCCH)
    - Used for Information needed for multicast reception.
  - Dedicated Control Channel (DCCH)
    - Used for carrying user-specific control information
  - Dedicated Traffic Channel (DTCH)
    - Used for the transmission of user data.
  - Multicast Traffic Channel (MTCH)
    - Used for the transmission of multicast data.

LTE Frames

- Type 1 LTE Frame Structure (LTE-FDD)
  - Has an overall length of 10 ms, divided into a total of 20 individual slots.
  - A LTE sub-frame consist of two slots.



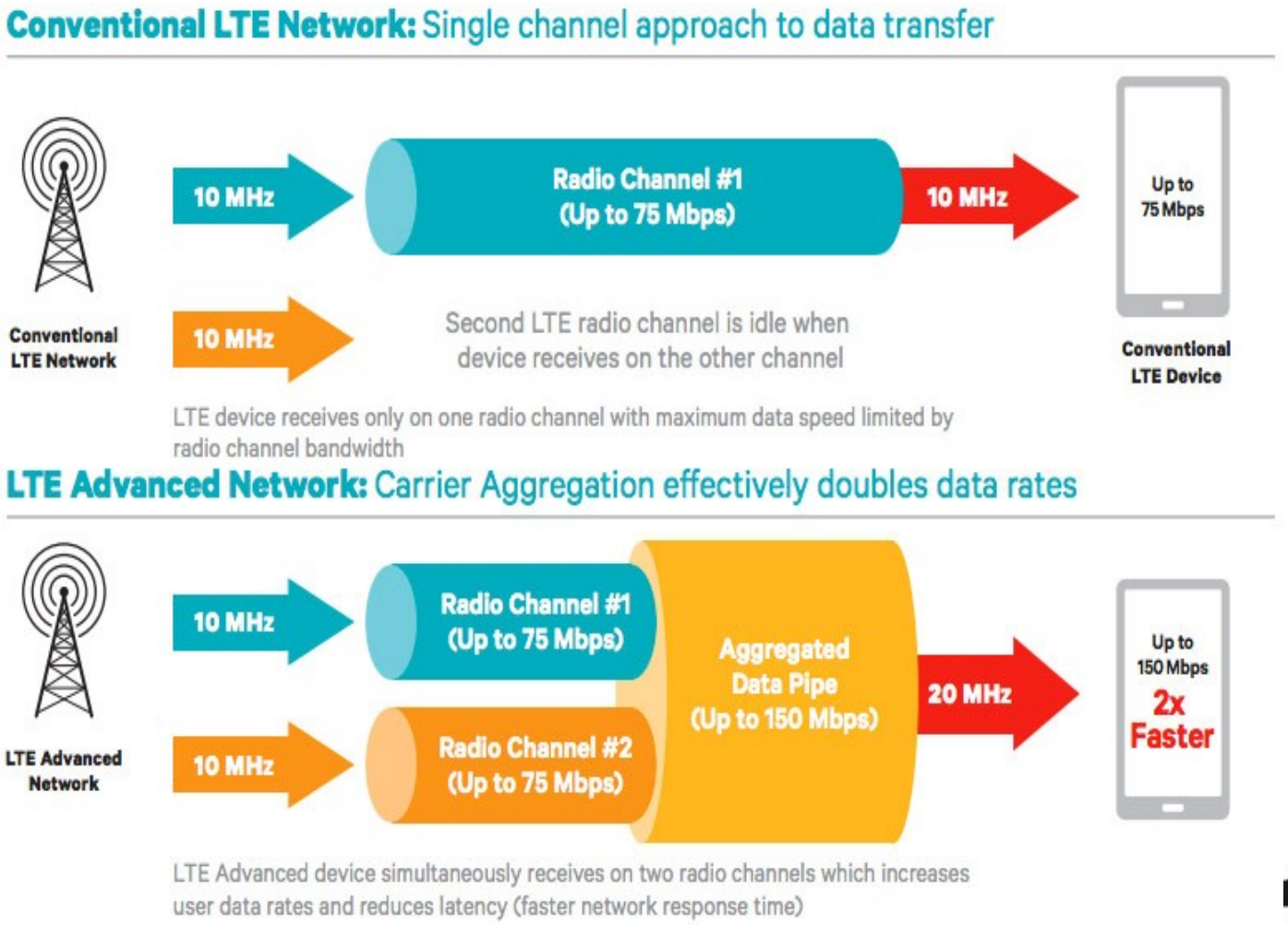
- Type 2 LTE Frame Structure (LTE-TDD)
  - Comprises two half frames, each 5 ms long.
  - LTE half-frames are further split into five subframes, each 1ms long.
  - Subframes may be divided into standard subframes of special subframes.
    - Special subframes consist of three fields: DwPTS - Downlink Pilot Time, Slot, GP - Guard Period, and UpPTS - Uplink Pilot Time Stot.



DwPTS - Downlink Pilot Time Slot
GP - Guard Period
UpPTS - Uplink Pilot Time Stot

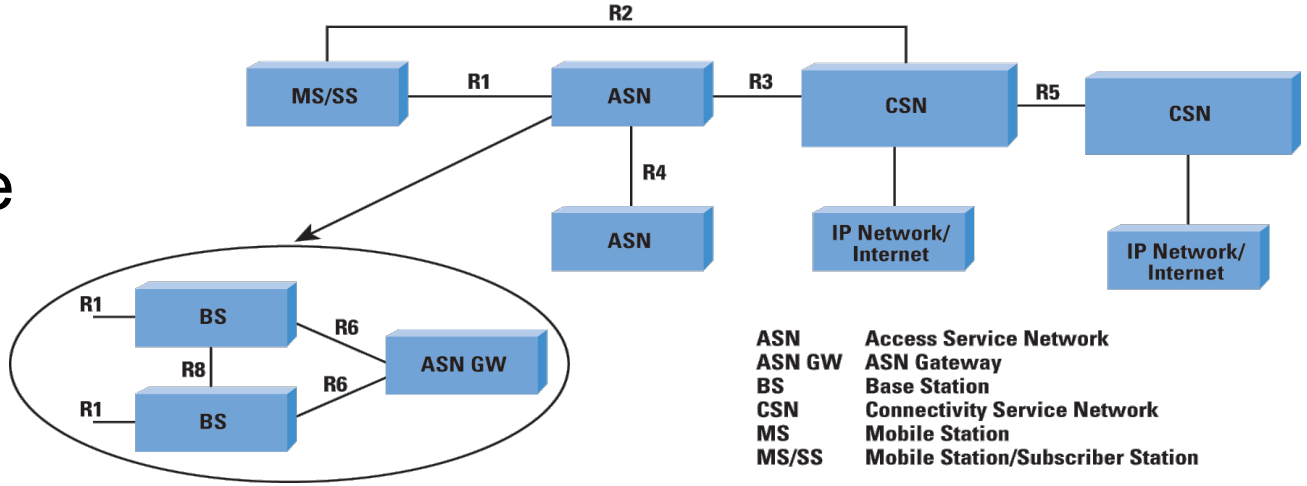
LTE-Advanced

- LTE-Advanced is the upgraded version of LTE.
  - Increases the peak data rates to about 1GBPS in the downlink and 500MBPS in the uplink.
- Utilizes higher number of antennas and added carrier aggregation feature.
  - Carrier aggregation can be used for both FDD and TDD.

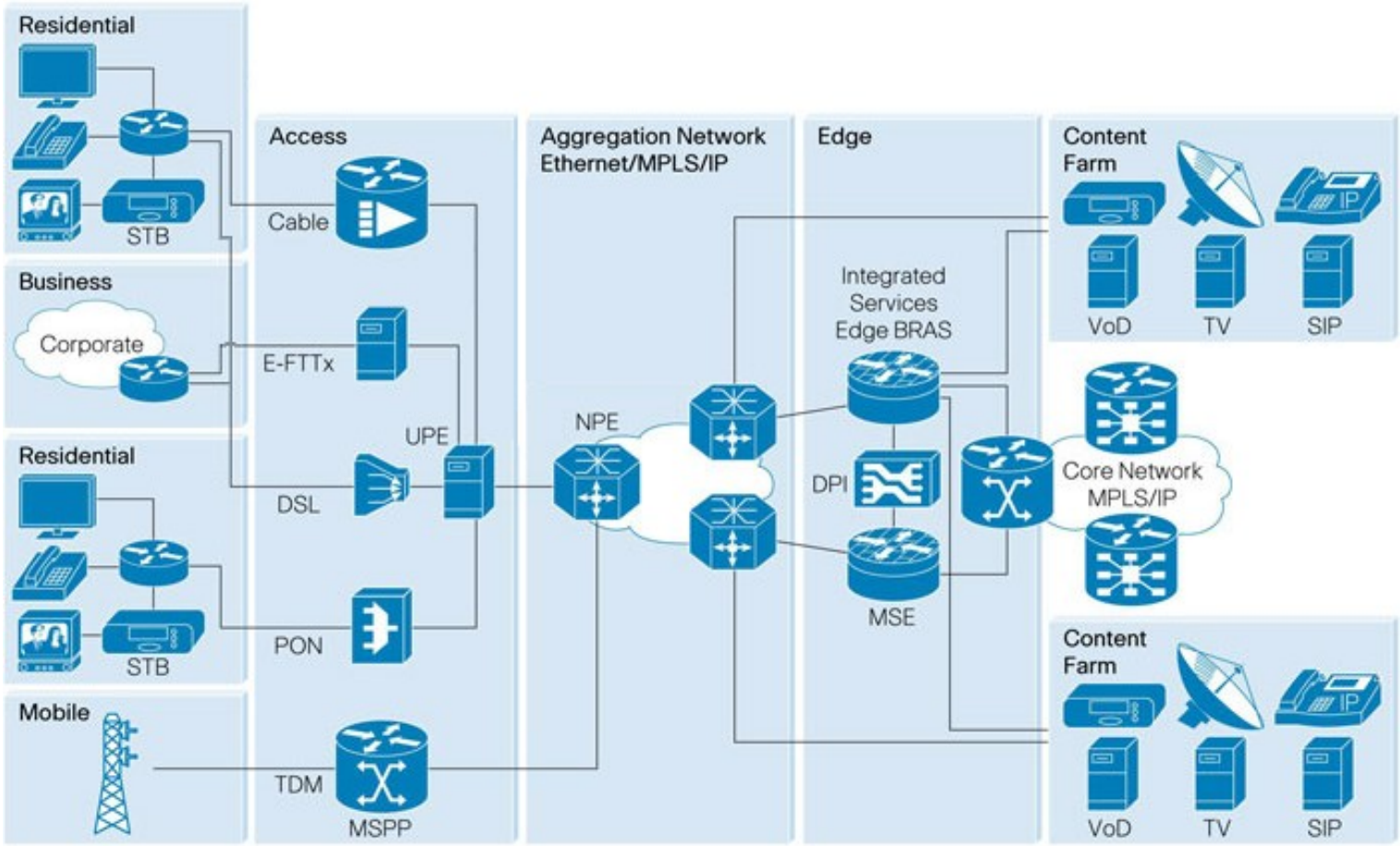


WiMax (802.16e)

- WiMAX stands for Worldwide Interoperability for Microwave Access and is defined under the IEEE 802.16 working group.
- 802.16e uses Scalable Orthogonal Frequency Division Multiplexed Access (S-OFDMA) and Frequency-Division Duplexing (FDD) .
- Mobile Stations (MS) connect to the Access Service Network (ASN).
- ASN is composed of one or more base stations (BSs) with one or more ASN gateways to connect to other ASNs and to the Connectivity Service Network (CSN).



WAN Access Architecture



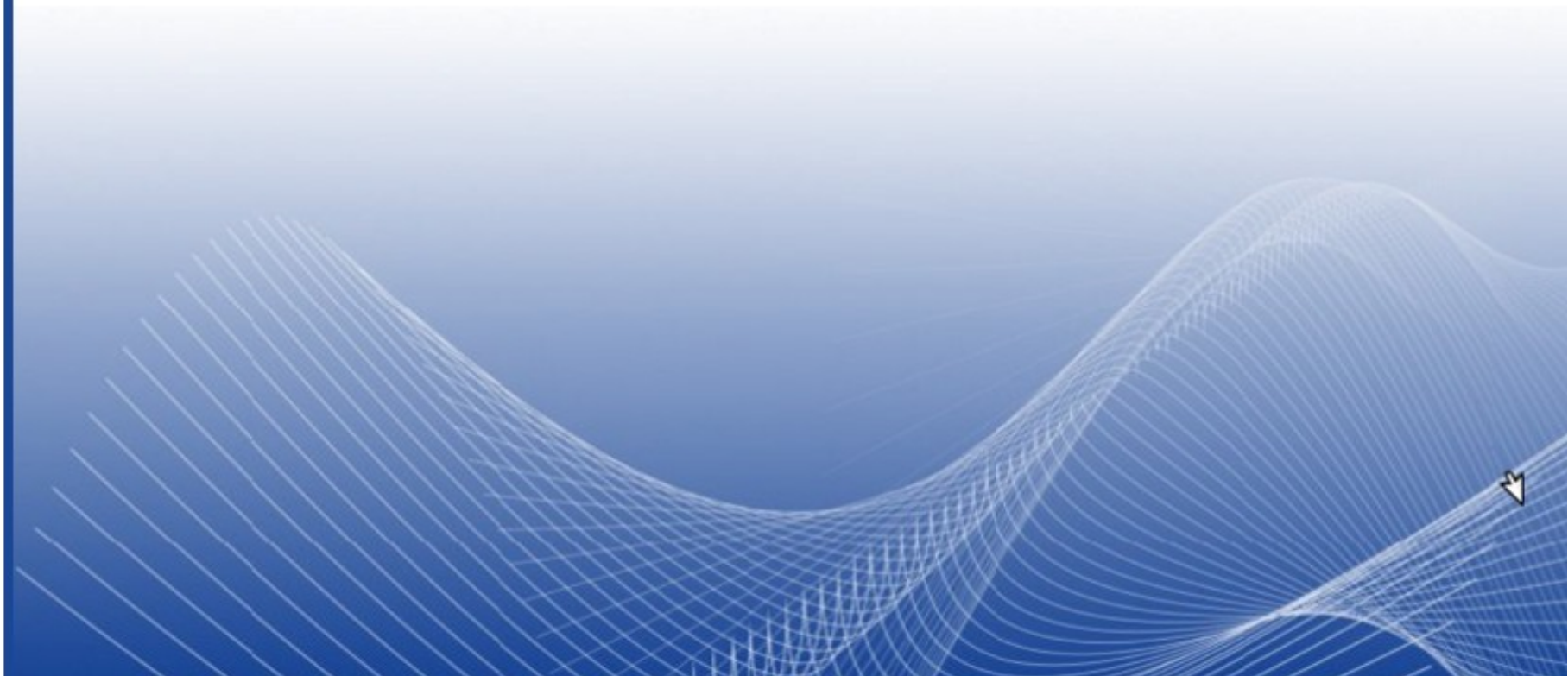
UPE - User-facing Provider Edge
NPE - Network-facing Provider Edge
BRAS - Broadband Remote Access Server
MSE- Mobility Services Engine

5G

- 5G systems are the next step in the evolution of mobile communication.
- Need to provide capabilities not only for voice and data communication as we know it today, but also for new use cases and new industries, and for a multitude of devices and applications to connect society.
- Research and standardization have started in many technology areas of fundamental importance for 5G, such as cloud and the Internet of Things (IoT).
- Will include the evolution of all parts of the network, such as core and management systems, as well as all protocol layers ranging from radio to applications.

Mobile IP

Arquitetura de Redes Avançadas



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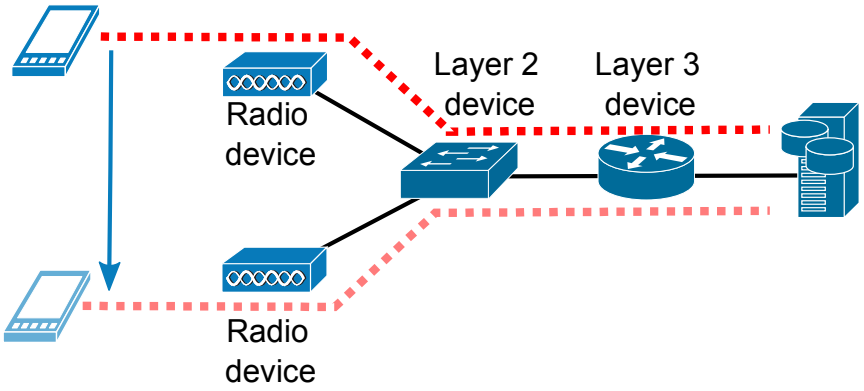
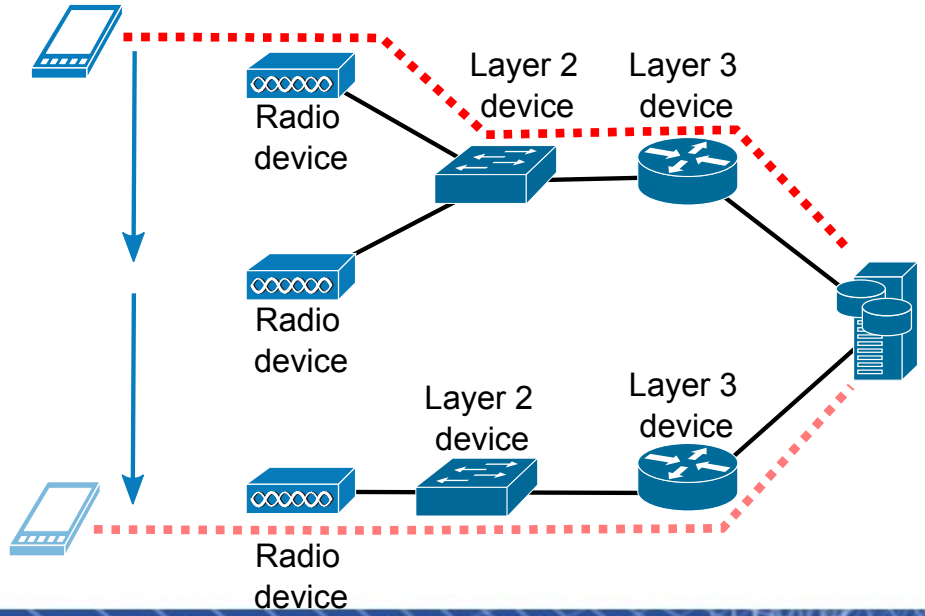
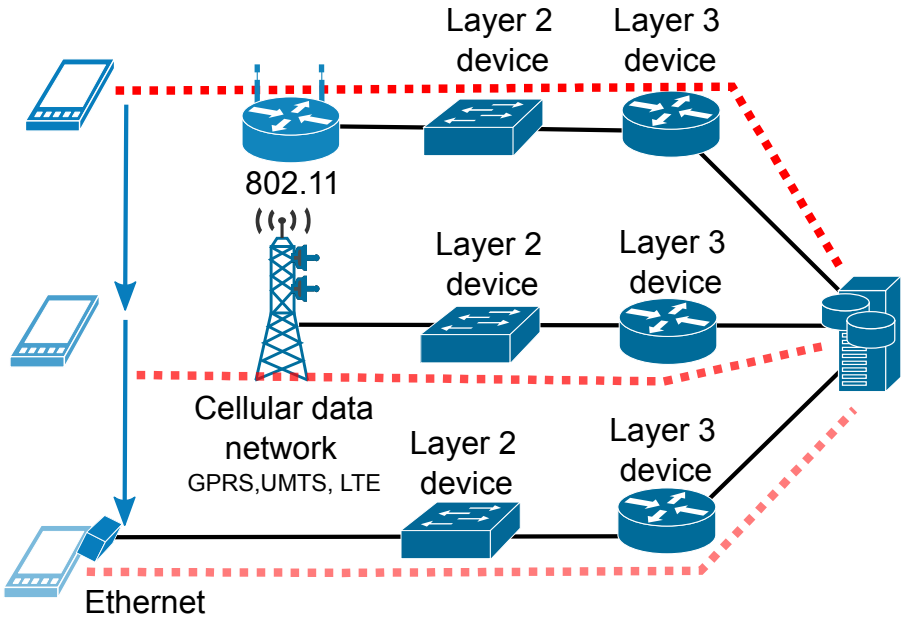
Mobility

- Layer 2 Mobility
  - Movement within a Layer 3 domain.
    - e.g., VLAN.
  - IP address does not change → Connections are preserved!
- Layer 3 Mobility
  - Movement between Layer 3 domains.
  - IP address changes → Connections must be reestablished!
- Multi-access Mobility
  - Movement between different tyupes of access networks,
    - e.g., WiFi to cellular, WiFi to Ethernet, etc...
  - IP address changes → Connections must be reestablished!

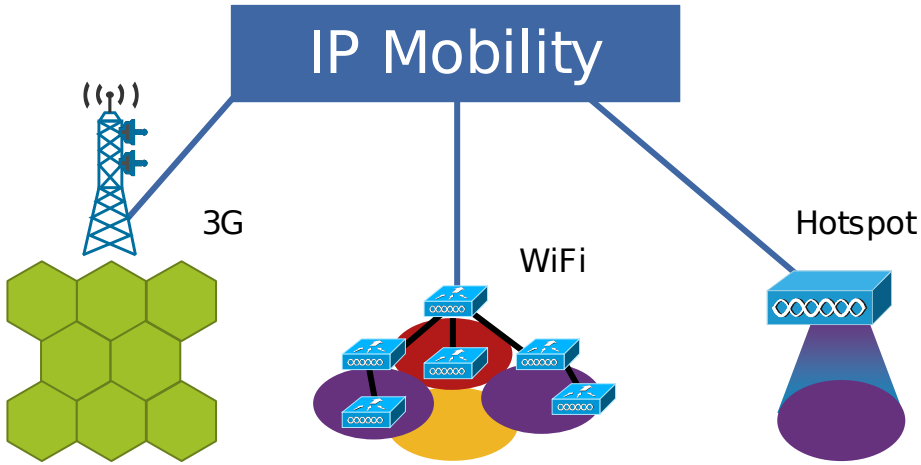


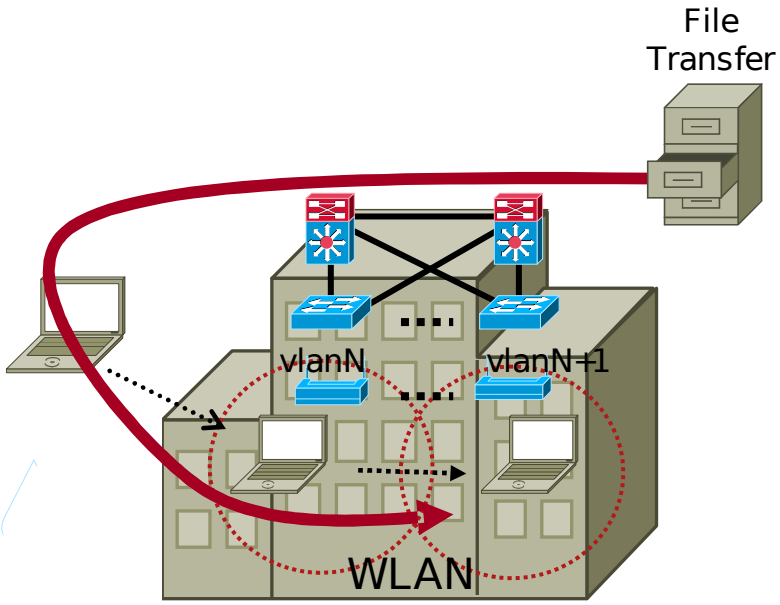




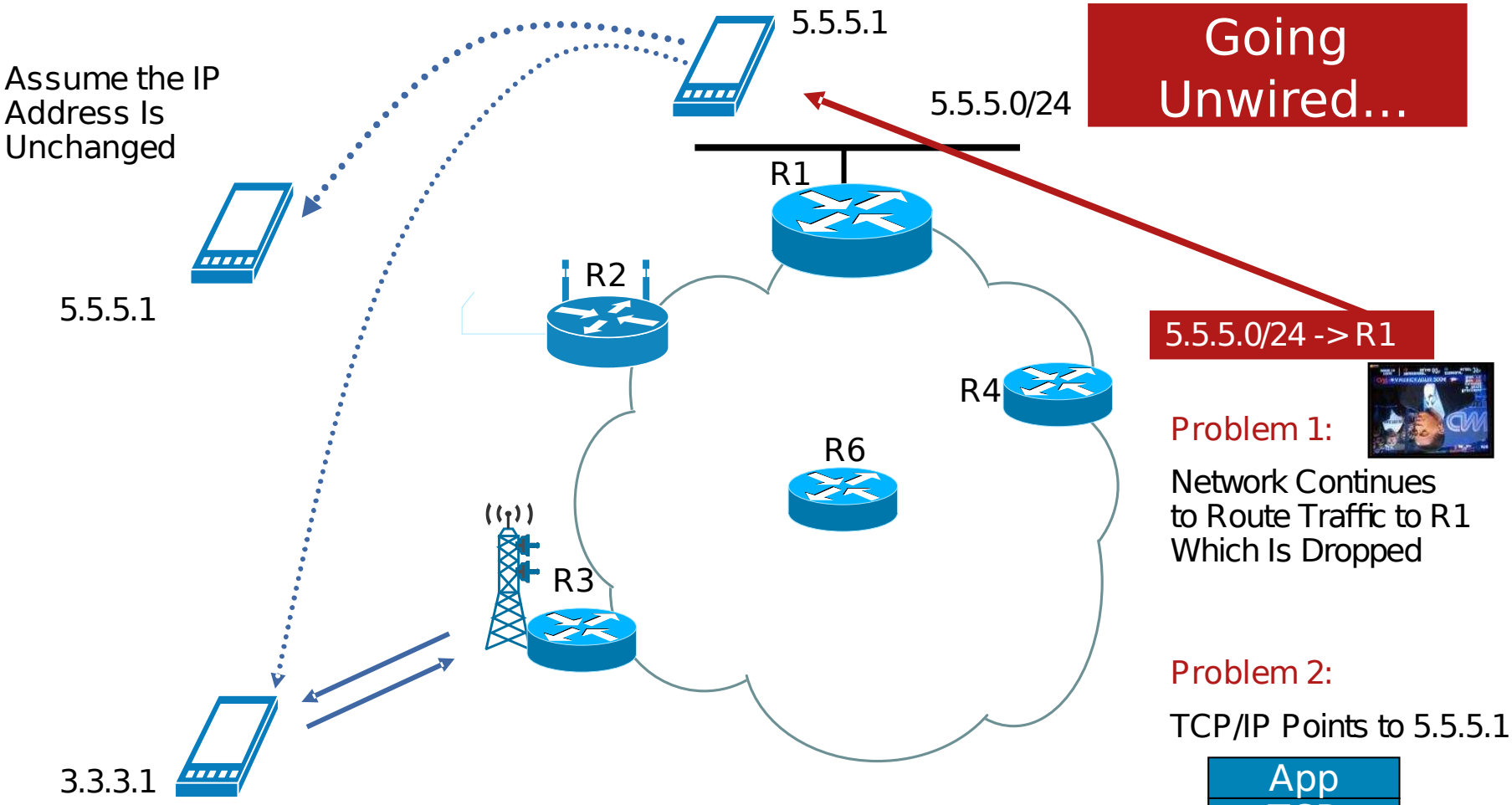
IP Mobility Support

- RFC 2002 (October 1996).
- Allow transparent routing of IP datagrams to mobile nodes in the Internet.
- Provides:
  - Extended coverage.
    - Creates one virtual large network, based on multi-acess and multi-IP networks.
  - Enhanced usability and effectiveness.
    - Always-on and uninterrupted network and application operation.
    - Low complexity from users' perspective
    - Better user/costumer satisfaction.
  - New services and applications.
    - Seamless Internet roaming, secure mobile VPN access, remote mobile office, video surveillance, ...





IP Mobility Concept: Problems



Problem 1:

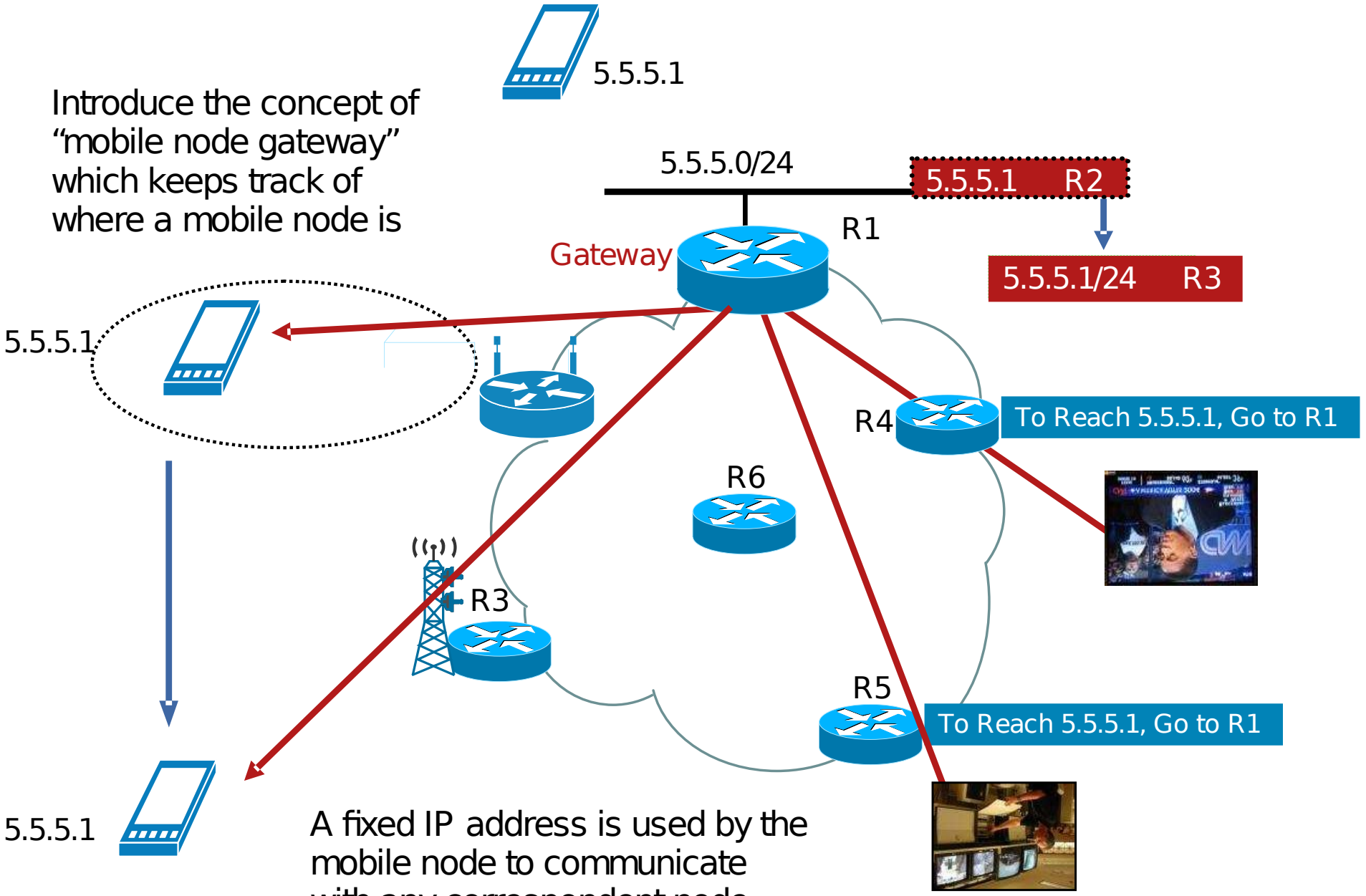
Network Continues to Route Traffic to R1 Which Is Dropped

Problem 2:

TCP/IP Points to 5.5.5.1

App
TCP
IP 5.5.5.1

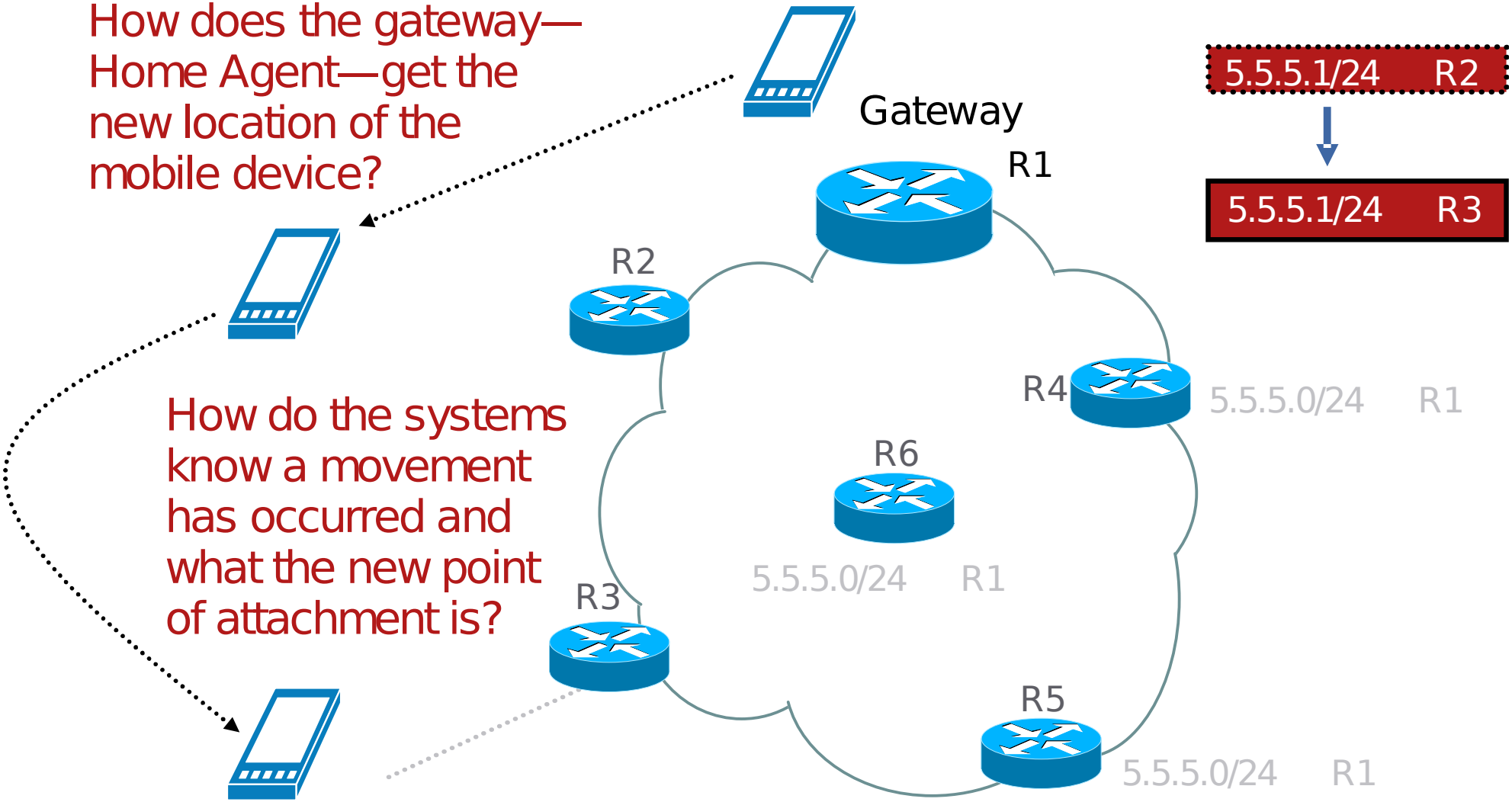
IP Mobility Concept: Basics



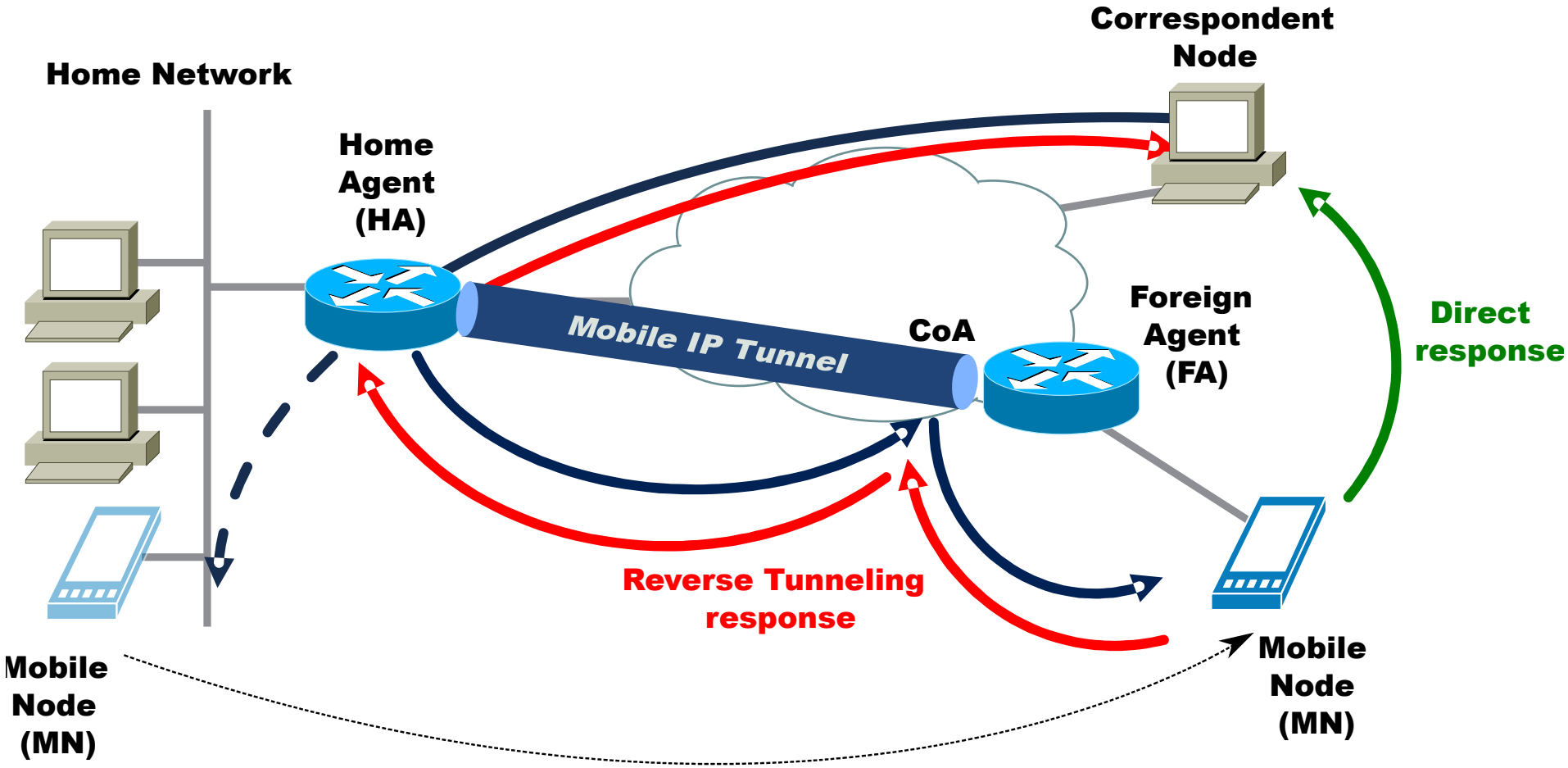
IP Mobility Concept: Requirements

How does the gateway—Home Agent—get the new location of the mobile device?

How do the systems know a movement has occurred and what the new point of attachment is?

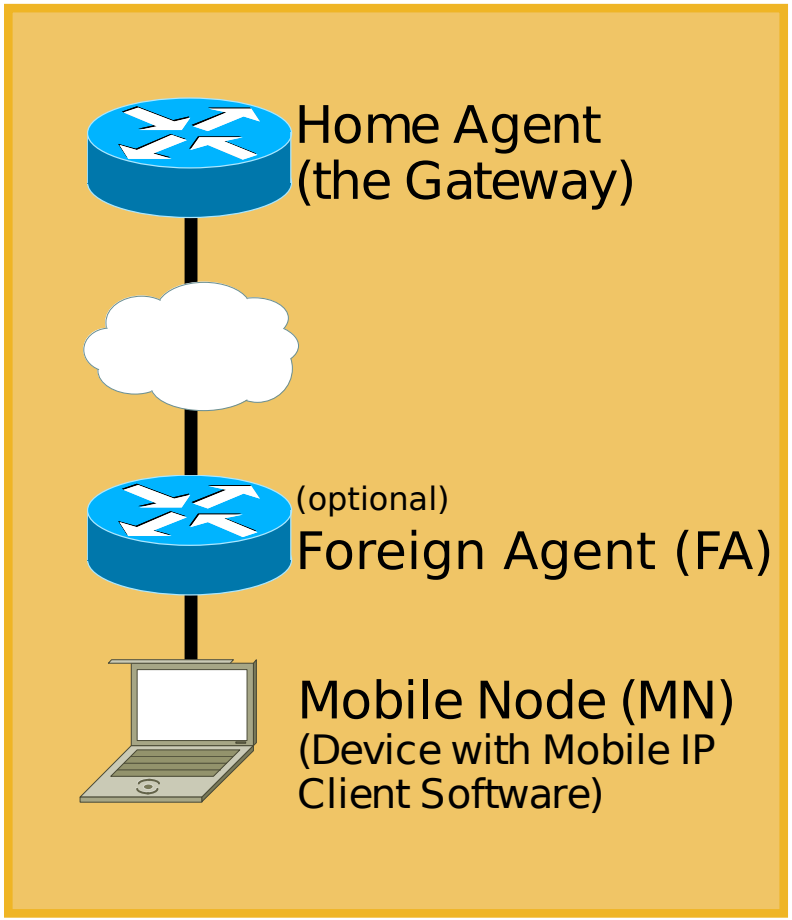


Solution: Mobile IP Tunnel

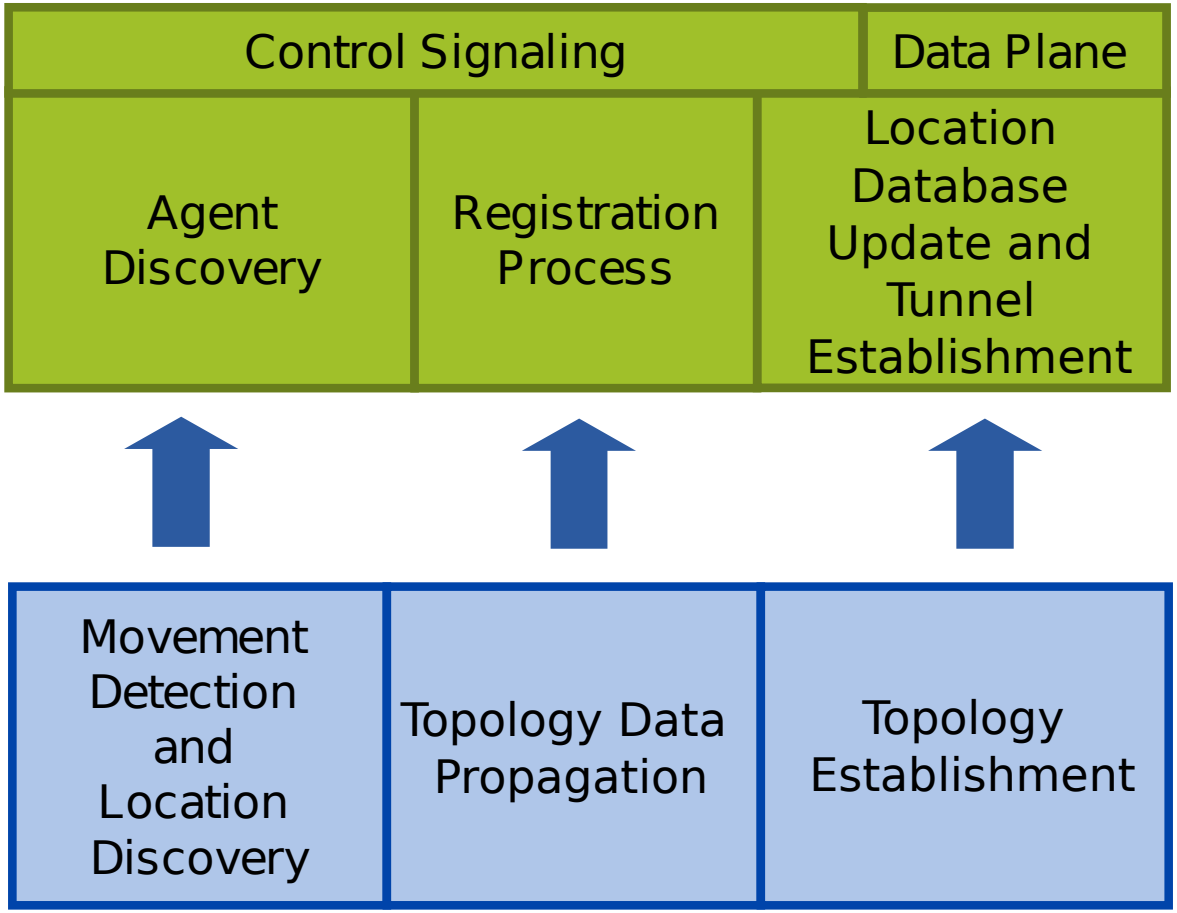


Mobile IP Components

Hardware Components

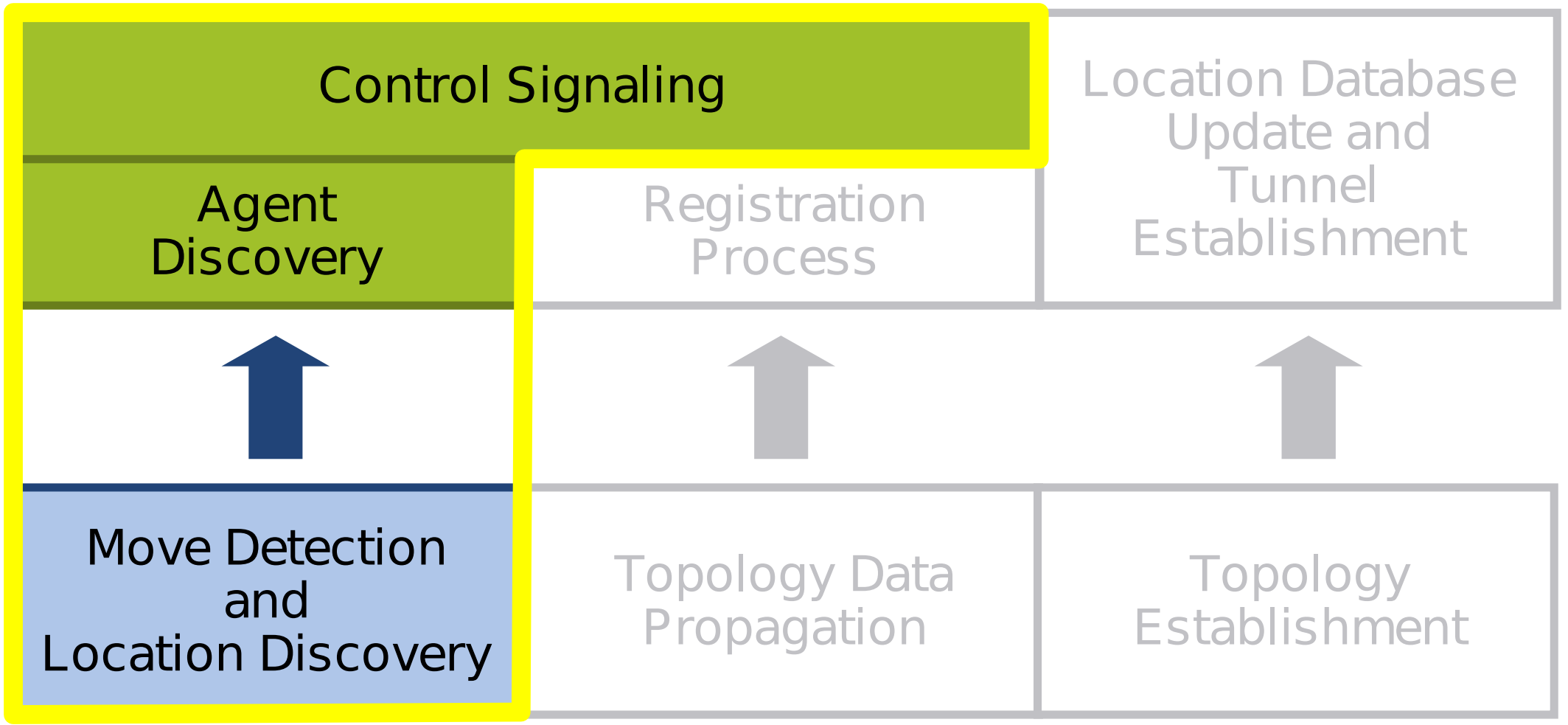


Software Components



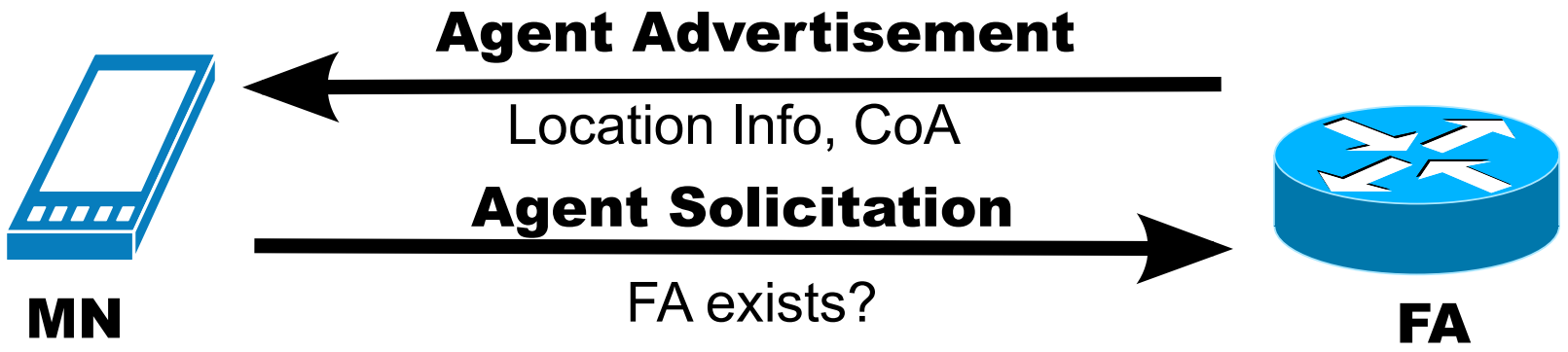
Conceptual Level

Movement Detection and Location Discovery



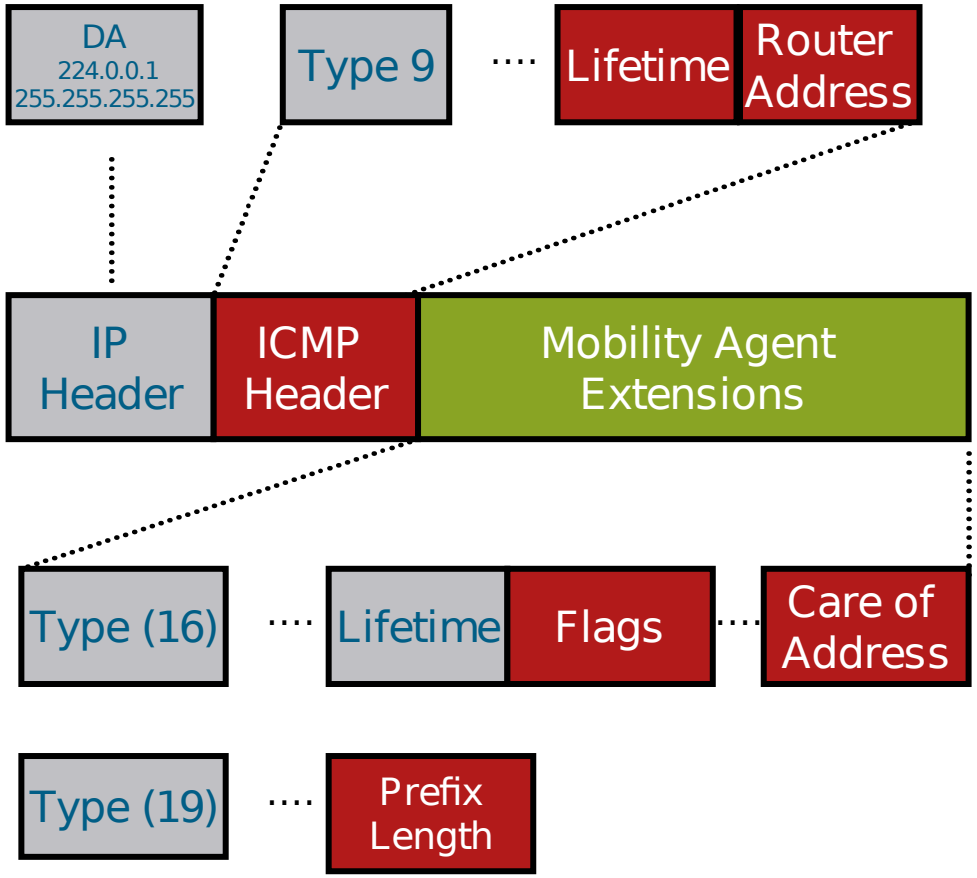
Movement Detection and Location Discovery: Overview

- Performed by the Mobile Node (MN) with assistance from network.
- Foreign Agent (FA) sends a message (**Agent Advertisement**) with
  - Location information, and
  - Care of Address (CoA): a FA address to which traffic for the MN will be forwarded
    - Without a FA the CoA is the address obtained locally by the MN (DHCP or IPv6 Router Advertisement) – Collocated CoA (CCoA).
- Mobile nodes evaluates the received location to detect movement and discover new location.
- Mobile node can sen a message to seek a FA (**Agent Solicitation**).

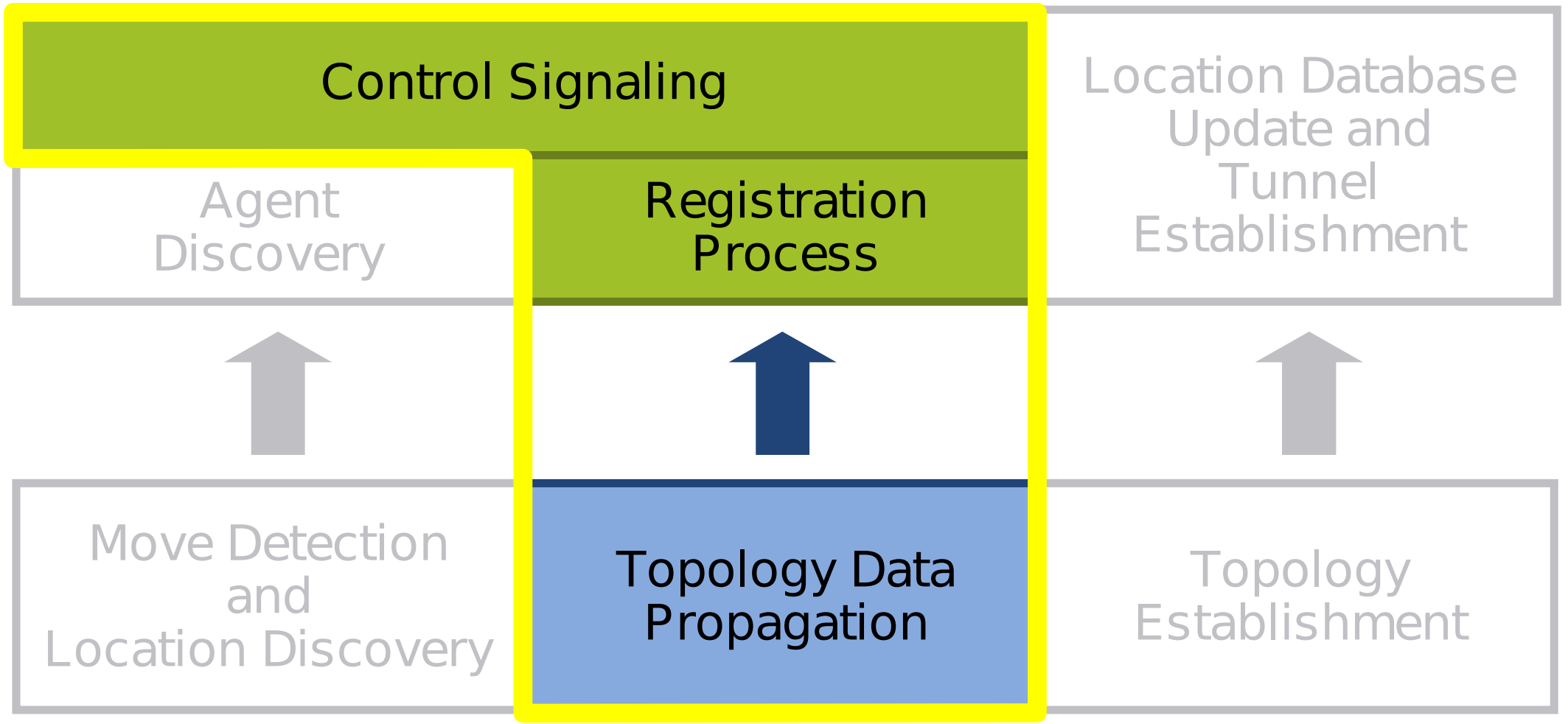


Agent Advertisement Message

- Is an ICMP message with
  - Lifetime and Router address(es).
  - A Mobility Agent Advertisement Extension is used to indicate that the message is being sent by a mobility agent (Home Agent - HA or Foreign Agent -FA) [type 16].
    - Sends Care-of Address (CoA).
  - A Prefix-Lengths Extension may follow the Mobility Agent Advertisement Extension [type 19].
    - Used to indicate the number of bits of network prefix that applies to each Router address announced.
- Periodically sent or sent in response to a solicitation from the MN.

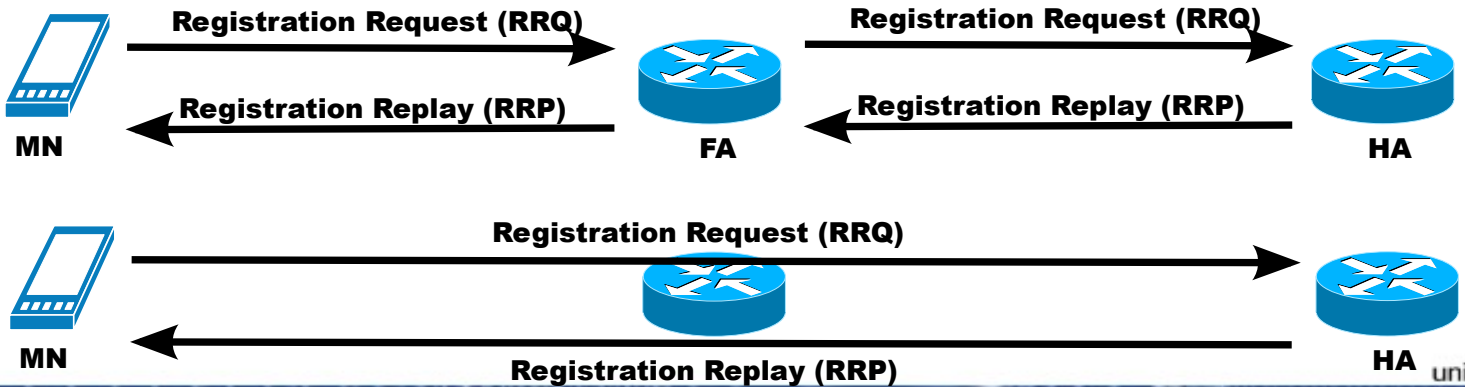


Topology Information Propagation



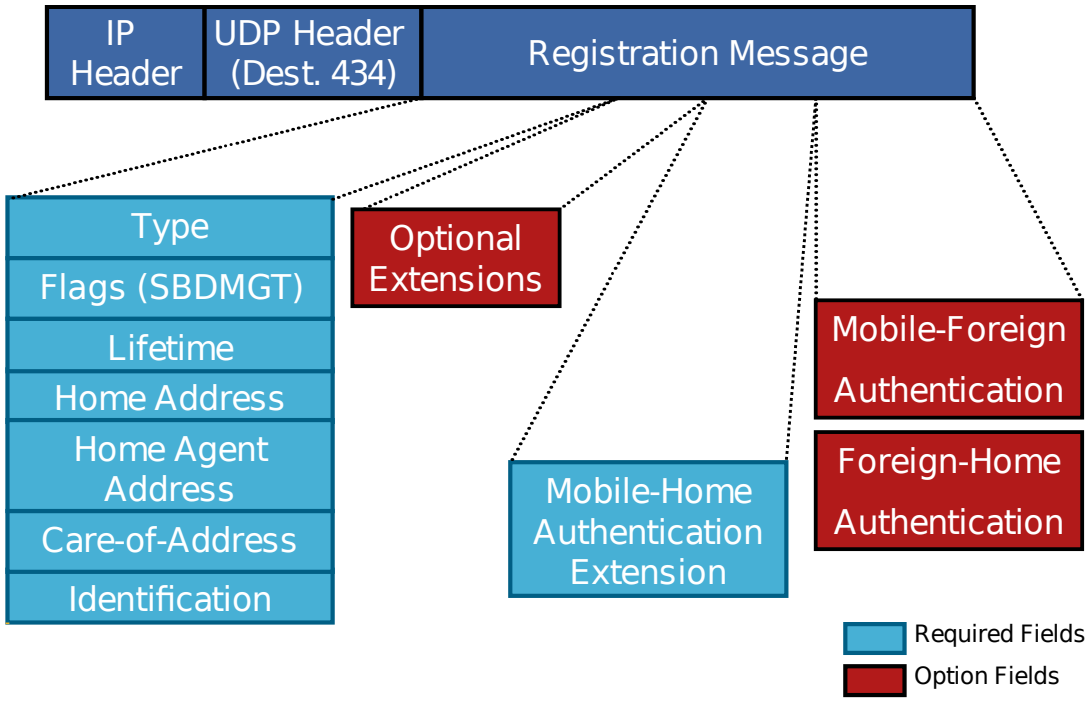
Registration Process

- Provides a flexible mechanism for mobile nodes to communicate their current reachability information to their home agent.
  - Requests forwarding services when visiting a foreign network,
  - Informs their home agent of their current CoA or CCoA,
  - Renew a registration which is due to expire, and/or
  - De-register when they return home.
- Registration messages exchange information between a mobile node, (optionally) a foreign agent, and the home agent.
- There are two different registration procedures
  - Via a foreign agent that relays the registration to the mobile node's home agent.
    - When the MN: (i) is registering a FA CoA, or (ii) is registering a CCoA that coincides with a CoA received in an Agent Advertisement.
  - Directly with the mobile node's home agent.
    - When the MN: (i) is registering a CcoA, or (ii) has returned to its home network and is (de)registering with the home agent.



Registration Request Message (RRQ)

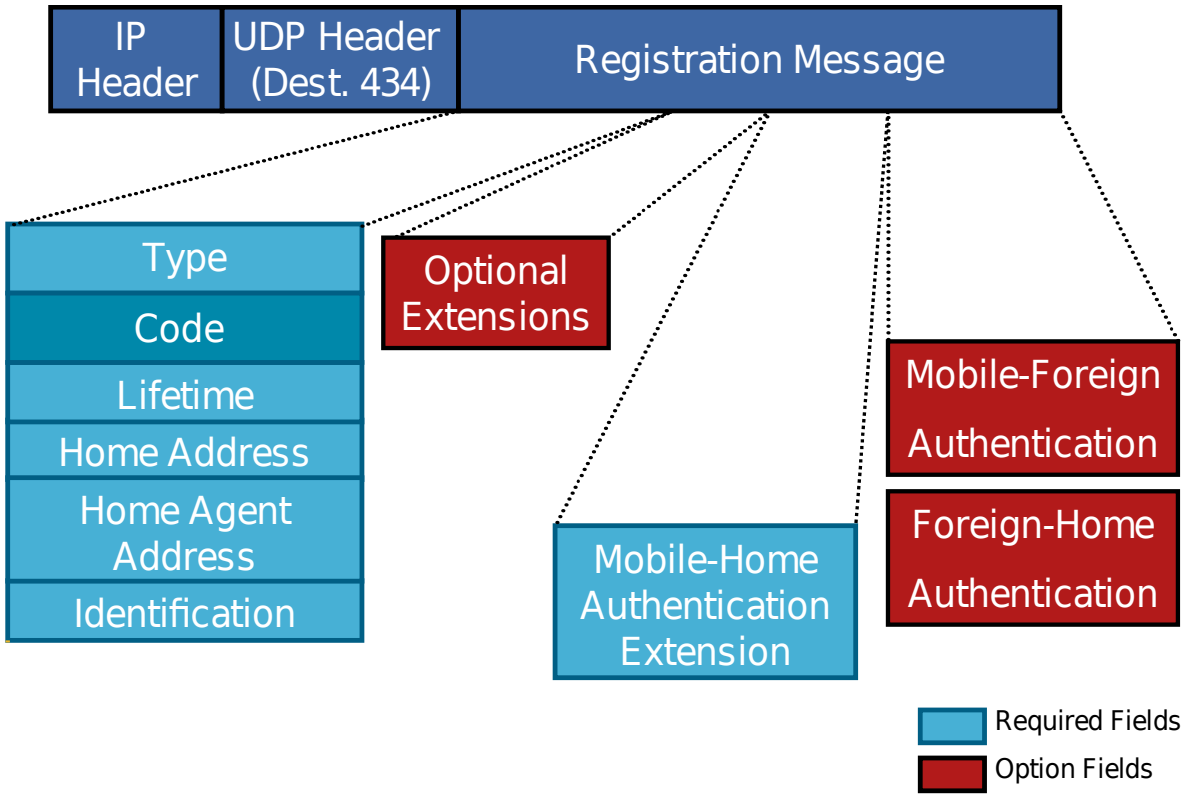
- UDP packet with Type=1 for RRQ.
- Flags
  - S - Simultaneous bindings, B-Broadcast datagrams, D-Decapsulation by mobile node, M-Minimal encapsulation, G- GRE encapsulation, and T- Reverse Tunneling requested.
- Lifetime, contains the number of seconds remaining before the registration is considered expired.
  - A value of zero indicates a request for de-registration.
  - A value of 0xffff indicates infinity.
- Home Address, contains the IP address of the mobile node.
- Home Agent, contains the IP address of the MN's home agent.
- Care-of Address, contains the IP address for the end of the tunnel.
- Identification, contains a 64-bit number, constructed by the mobile node, used for RRQ with RRP.



- Required Extension
  - Mobile-Home Authentication
    - Always an authorization-enabling for registration messages
- Optional Extensions
  - Mobile-Foreign Authentication
  - Foreign-Home Authentication

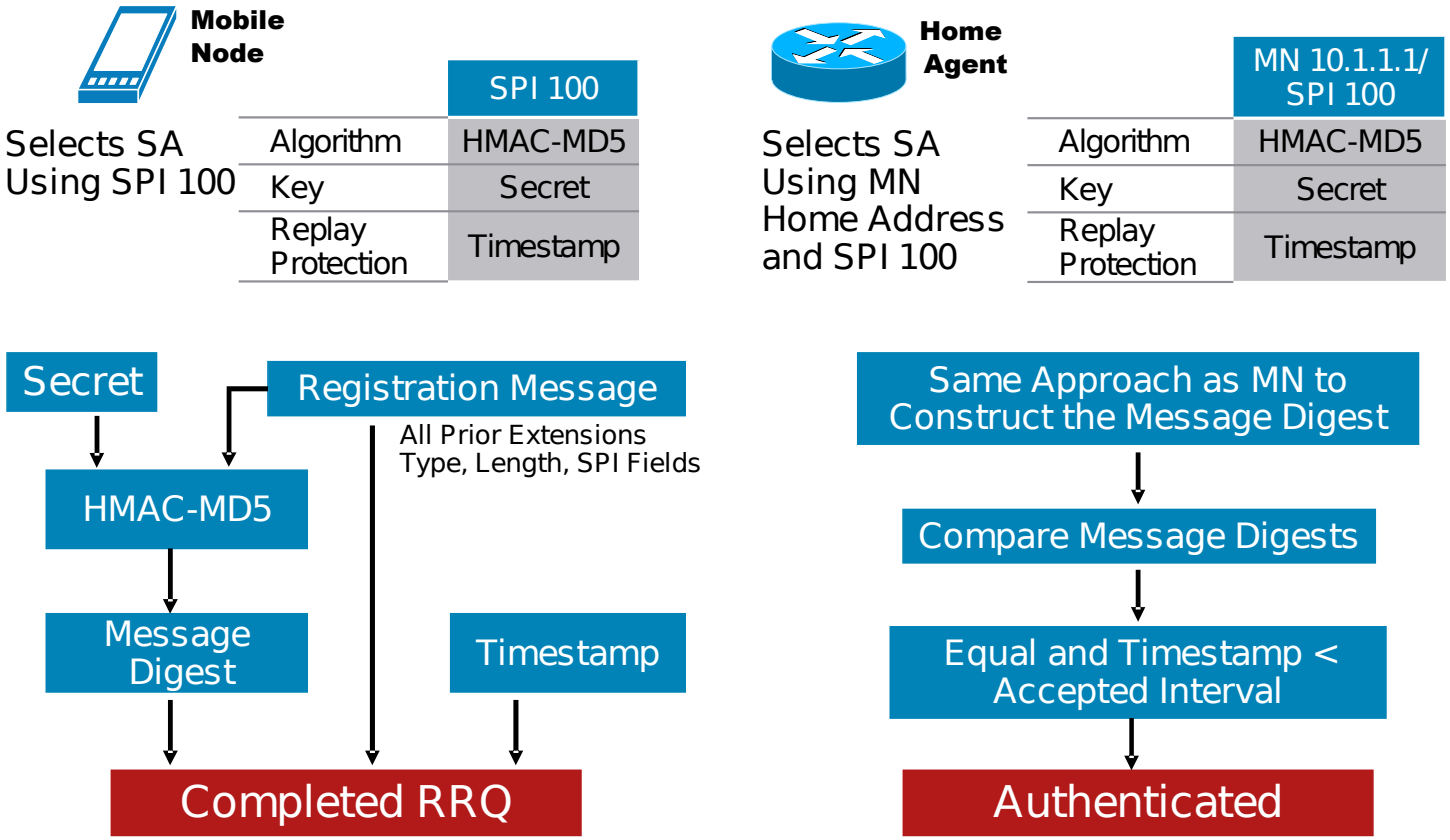
Registration Reply Message (RRP)

- UDP packet with Type=3 for RRP.
- New field Code indicating the result of the Registration Request.
  - Registration successful:
    - 0 registration accepted
    - 1 registration accepted, but simultaneous mobility bindings unsupported
  - Registration denied by the FA:
    - 64 reason unspecified
    - 65 administratively prohibited
    - 66 insufficient resources
    - 67 mobile node failed authentication
    - 68 home agent failed authentication
    - 69 requested Lifetime too long
    - 70 poorly formed Request
    - 71 poorly formed Reply
    - 72 requested encapsulation unavailable
    - 73 reserved and unavailable
    - 77 invalid care-of address
    - 78 registration timeout
    - 80 home network unreachable (ICMP error received)
    - 81 home agent host unreachable (ICMP error received)
    - 82 home agent port unreachable (ICMP error received)
    - 88 home agent unreachable (other ICMP error received)



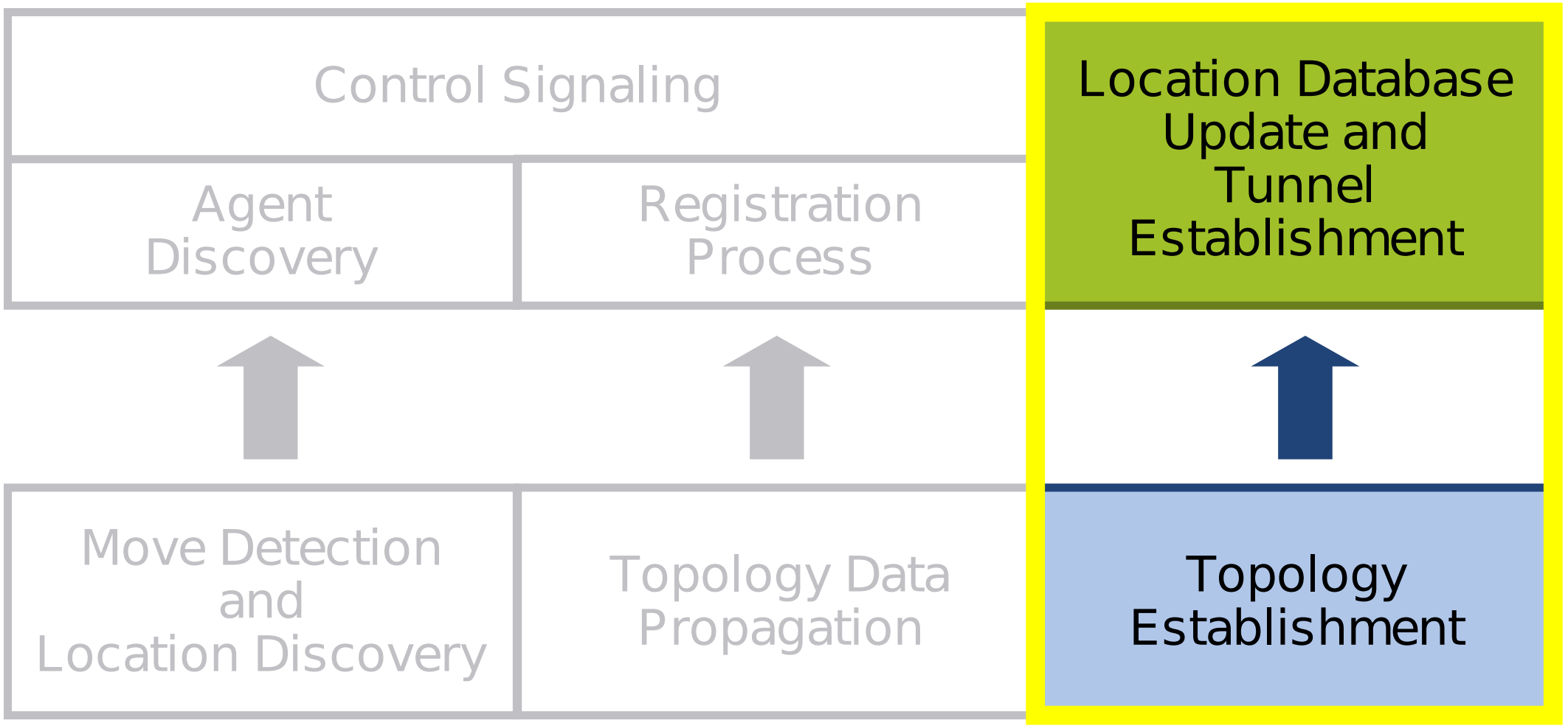
  - Registration denied by the HA:
    - 128 reason unspecified
    - 129 administratively prohibited
    - 130 insufficient resources
    - 131 mobile node failed authentication
    - 132 foreign agent failed authentication
    - 133 registration Identification mismatch
    - 134 poorly formed Request
    - 135 too many simultaneous mobility bindings
    - 136 unknown home agent address

Mobile IP Authentication

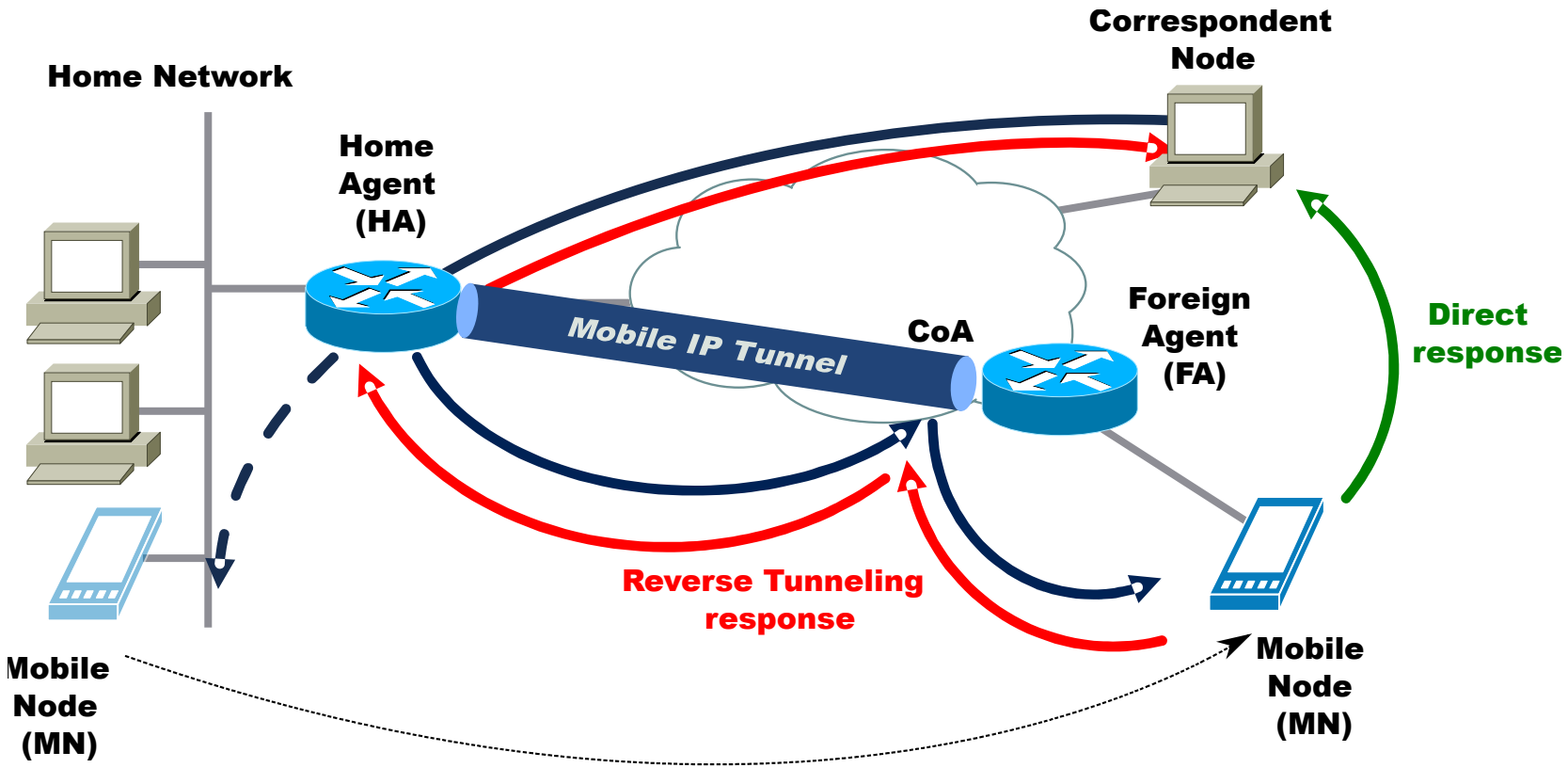


- Can occur between any two mobile IP components.
  - Mandatory between MN and HA.
- Security Association (SA)
  - Set of security parameters used to sign a message (hash algorithms, key size, replay protection – timestamp or Nonce.)
- Security Parameter Index (SPI)
  - Is a numeric identifier for the SA. Allows multiple SA and multiple sessions between two devices.
- Key management
  - PKI with manual key distribution.

Topology Establishment



Topology Establishment



- Location database update
  - Contains CoA (current point of attachment) of a MN.
  - Similar to a routing table. Known as “binding table” on a HA, and as “visitor table” on a FA.
- Tunnel creation
  - A logical link/interface to forward traffic to and from a MN.
  - Can be IP-IP, GRE, or UDP.
  - Established between HA and CoA FA or between HA and CCoA MN.
- MN responses can be routed directly or using the tunnel (reverse tunneling).

IPv6: Intrinsic Mobility

- Mobility in IPv6:
  - Developed in the basis of IPv6.
  - There are no registration messages, but resorts intensively to Binding Updates – they have to be supported by the MNs.
  - Uses self-configuration capabilities of IPv6.
  - Better support in terms of options at IP level (e.g. Destination options).
  - MN is always ‘connected’ to the HA, via the permanent Binding that they maintain.