Telecommunication Services Engineering (TSE) Lab

Chapter III –
4G Long Term Evolution (LTE) and Evolved Packet Core (EPC)

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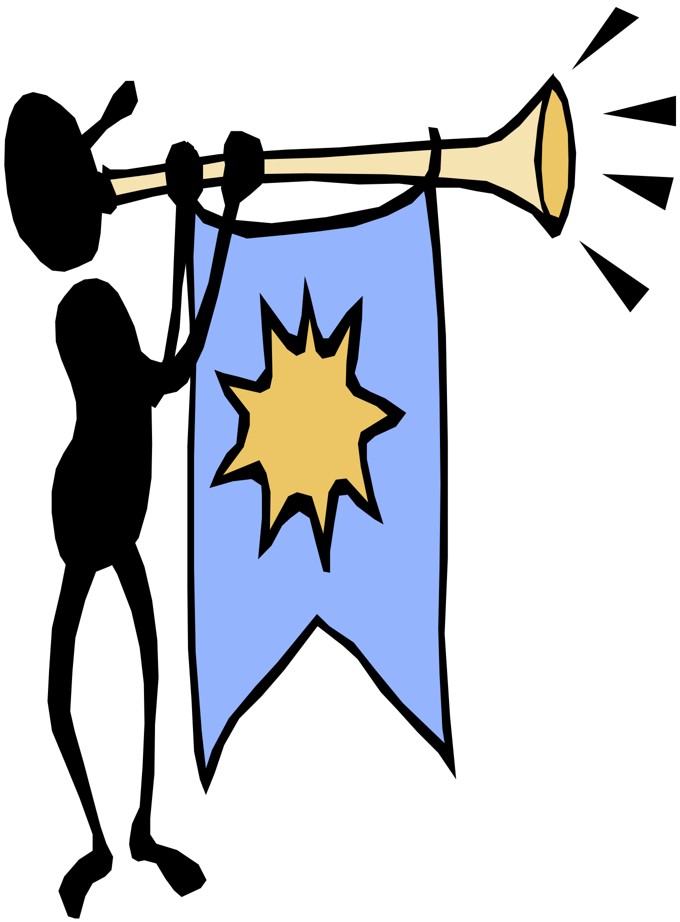
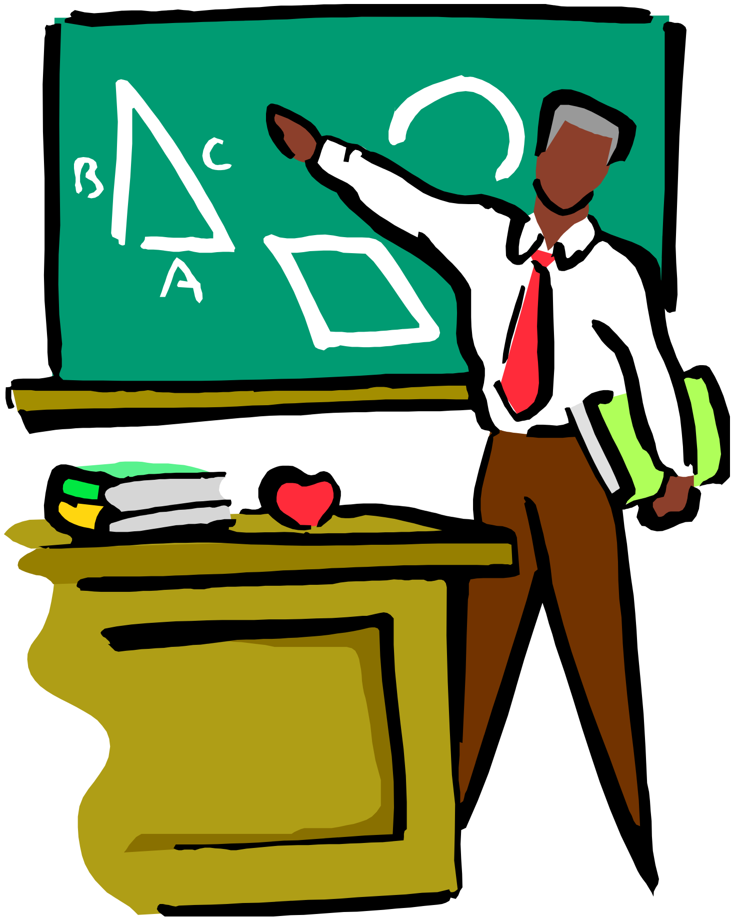
Outline



1. LTE
2. EPC architectures (Basic and advanced)
3. Mobility management in EPC
4. QoS management in EPC

Telecommunication Services Engineering (TSE) Lab

LTE



LTE

LTE (Long Term Evolution) : Radio access network

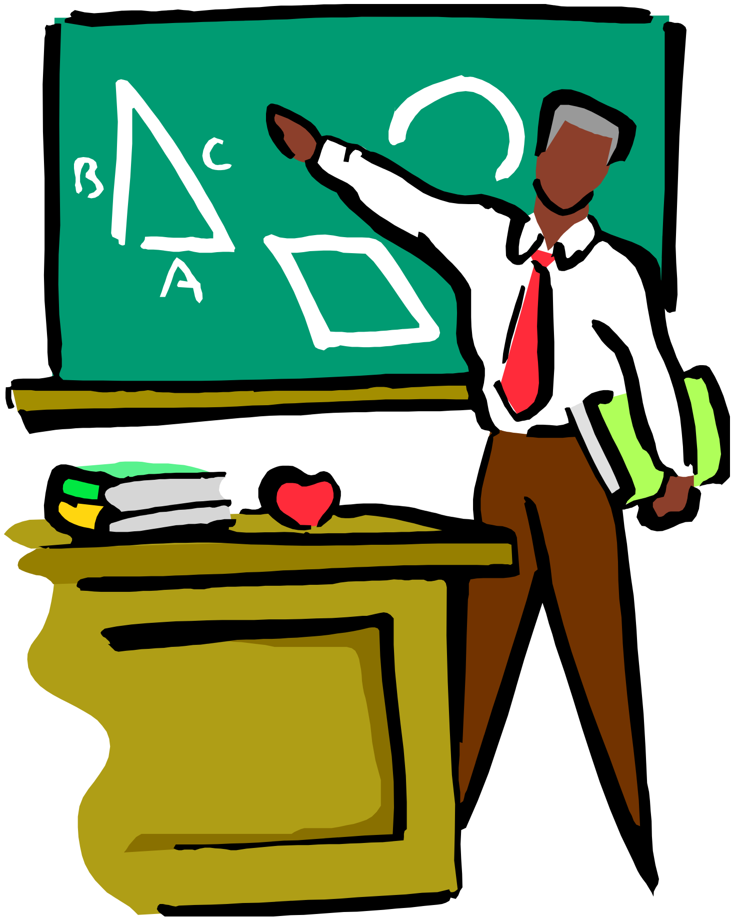
- **4G Transport**
  - **LTE:**
    - **Radio access network known also known as Evolved - UTRAN**
      - Base stations called eNodeB
      - OFDM technology
  - IP
  - UDP/TCP/ SCTP (a more reliable alternative to TCP)

LTE

LTE (Long Term Evolution)

- **Bandwidth**
  - Downlink: XXX Mbits/s (Peak rates up to 300 Mbits/s)

EPC architectures



- Principles
- Basic architecture
- More advanced architectures

EPC architecture

Evolved Packet Core (EPC)

- **Above LTE 4G transport**
  - **Can accommodate other radio access networks such as:**
    - Legacy 3GPP radio access
      - GPRS (2.5G), UTRAN (3G), HSPA (3.5G)
    - Non 3GPP radio access
      - Wimax
      - Wifi
      - CDMA 2000

EPC - architecture

- **Key principles**
  1. **Flat architecture**

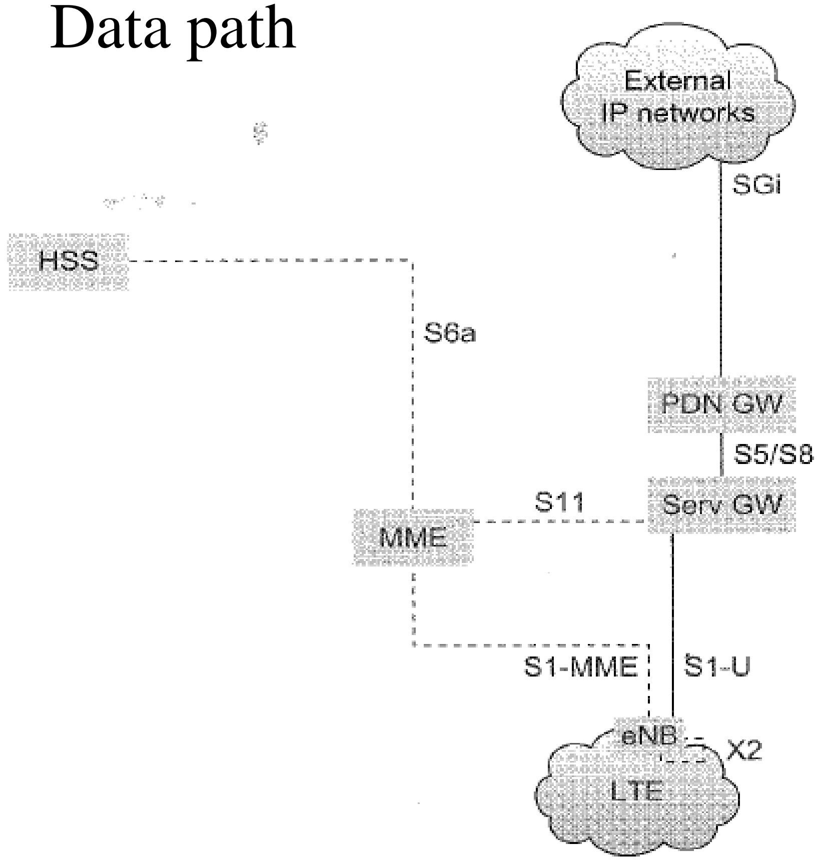
     As few entities/nodes as possible
  2. **Clean separation between control / signalling path and data path**

     Note:
     - signalling has a very broad meaning and does not mean multimedia session signalling in this context
       - Means control of data path

EPC Basic architecture

Basic EPC architecture for LTE (Reference 1)

- Dotted lines: Signalling/control path
- Solid lines: Data path



EPC Basic architecture

Evolved Packet Core (EPC)

The few nodes

Signalling / control path

HSS

- Subscriber data base

Mobility Management Entity (MME)

- Controls the EnodeB (Base stations)
- Interacts with the HSS
  - Find out if for instance the user is allowed to use the EPC network
- Mobility (To be discussed in details later in the chapter)
- Security

EPC – basic architecture

Evolved Packet Core (EPC): The few nodes

Signalling / control path

HSS

Mobility Management Entity (MME)

A note on the protocols

- SCTP (Stream Control Transport Protocol) used by MME for reliability reasons
  - **SCTP is a more reliable alternative to TCP**
    - Multi homing
    - Four way handshaking
- Diameter over SCTP is used for interactions with the HSS

EPC – Basic architecture

Evolved Packet Core (EPC): The few nodes

Data path

PDN Gateway

Gateway towards external networks / nodes such as:

- Internet
- Application servers
- IMS
- Other service delivery platforms

EPC Basic architecture

Evolved Packet Core (EPC): The few nodes

Data path

Serving Gateway ("The heart", "The switch" …)

Belongs to both signalling/control path and data path

On the signalling/control path

- Control the MME
- Mark "packets" for QoS differentiation purpose (To be discussed later in the chapter)

On the data path

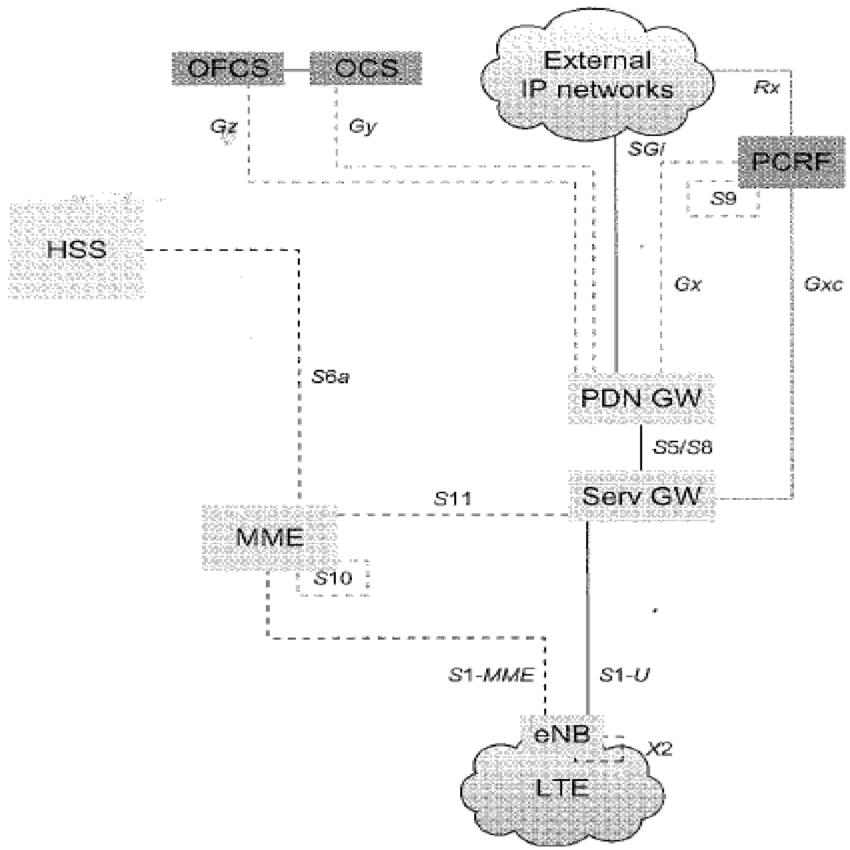
- Buffers data as appropriate

EPC – A more advanced architecture

A more advanced EPC architecture for LTE (Reference 1)

. Dotted lines: Signalling/control path

. Solid lines: Data path



EPC – A more advanced architecture

Evolved Packet Core (EPC)

- **A more advanced architecture: The new entities**

  2. **Policy and Charging Rule Function (PCRF)**

     Policy: Treatment a specific IP flow shall receive

     QoS management (preferential treatment)

     Charging (e.g. on-line credit card verification)

EPC – A more advanced architecture

Evolved Packet Core (EPC)

- **A more advanced architecture: The new entities**

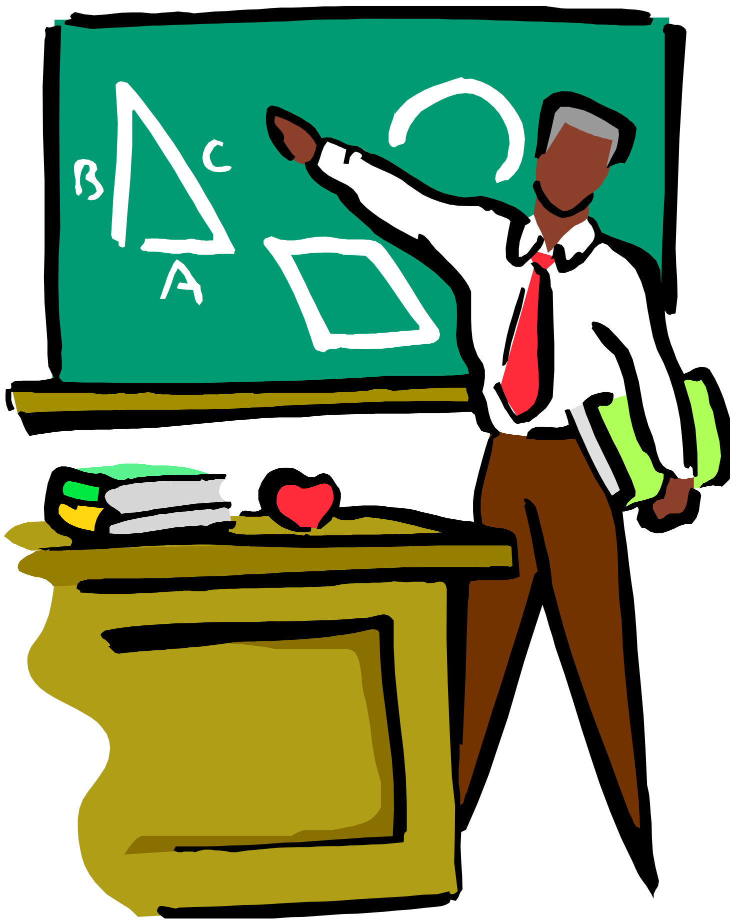
Online charging system (OCS) and offline charging system (OFCS)

Interact with PDN gateways for charging purpose

Based on parameters such as:

- Time
- Volume
- Event

Mobility management in EPC

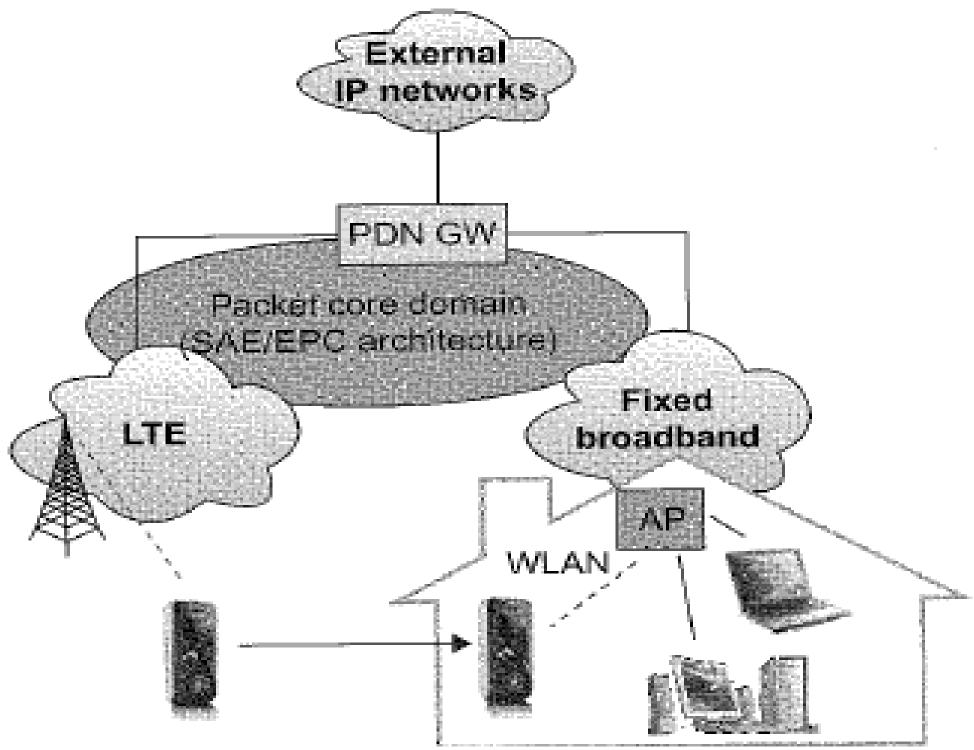


- A scenario
- Background information on mobile IP
  - Mobile IPv4 (MIPv4)
  - Mobile IPv6 (MIPv6)
  - Other mobile IP protocols relevant to EPC
    - Proxy Mobile IPv6 (PMIPv6)
    - Dual Stack Mobile IPv6 (DSMIPv6)
- Mobility management mechanisms in EPC

Mobility management scenario

Evolved Packet Core (EPC)

- Mobility management: scenario



Mobility management scenario

Evolved Packet Core (EPC)

- **Mobility management: scenario**
  - Assumption:
    1. User-equipment (end-user device) supports both LTE and WLAN
    2. End-user move from outdoors (i.e. LTE) indoors (i.e. WLAN connected to fixed broadband)

Problem:

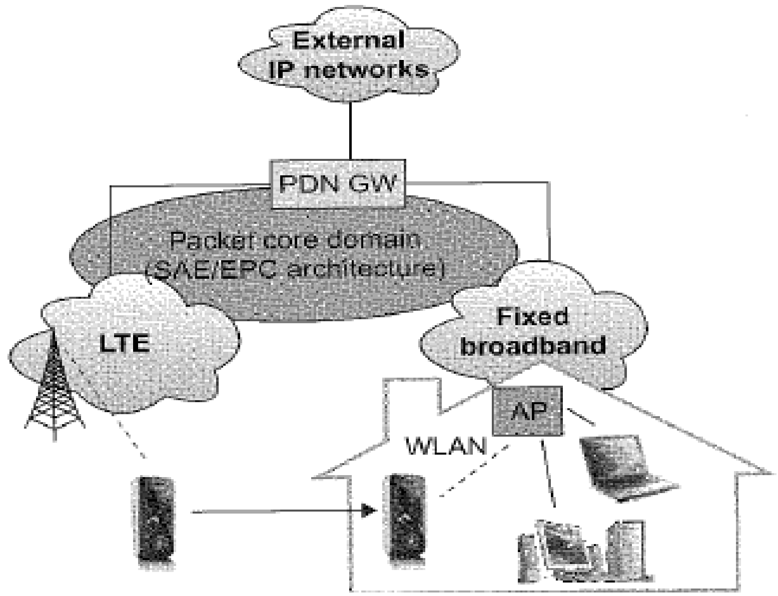
How to maintain sessions (i.e. on-going skype session, video on demand session)

Solution:

Mobile IP (IPv6 version)

Mobility management scenario

- 1. Draw the full mobility sequence diagram when the user moves outdoors to indoors assuming that PMIPv6 is used.



MIPv4

- Mobile IPv4
  - Key concepts
    - Mobile host (MH)
    - Two IP addresses
      - Home address (HoA)
      - Care of (COA) address
    - Two new entities
      - Home agent (HA)
      - Foreign agent (FA)

MIPv4

- Mobile IPv4
  - Key phases
    - Agent discovery
    - Registration
    - Routing

MIPv4

Mobile IPv4

- Agent discovery (i.e. Need to detect MH has changed point of attachment)
  - Agent advertisements transmitted periodically by HA and FA
  - Extension of Internet Control Message Protocol (ICMP)
  - Detection may be based on lifetime field of the router advertisement
    - ICMP
      - » Reports when something unexpected happens / Test Internet
        - » Ex: destination unreachable, time exceeded, echo/echo reply

MIPv4

- Mobile IPv4
  - Registration
    - Goal: Make HA aware of the whereabouts of MH
    - May (or may not) go through FA
    - Two messages (carried over UDP)
      - Registration request
      - Registration reply

MIPv4

- Mobile IPv4
  - Routing
    - HA
      1. Intercepts packets sent to MH home address
         - » Gratuitous Address Resolution Protocol (ARP) packets
           - » ARP address maps IP address on MAC address
           - » Gratuitous ARP packets enables the re-directions to HA of all packets sent to MH home address

MIPv4

- Mobile IPv4
  - Routing
    - HA
      1. Tunnels packets to CoA
         - » End of tunnel
           - » MH
             - » Or
           - » FA

MIPv6

- Mobile IPv6
  - Same fundamental principles as Mobile IPv4
    - Some differences
      1. No foreign agent (FA)
         - » IPv6 MH acquire their CoA without the assistance of FA
      2. HA discovery done using anycast
         - » More efficient than the broadcast used in Mobile IPv4

MIPv6

- Mobile IPv6
  - Key concepts
    - Mobile host (MH)
    - Two IP addresses
      - Home address (HoA)
      - Care of (COA) address
    - 1 new entity
      - Home agent (HA)

Mobile IPv6

- Mobile IPv6
  - Three phases
    - Bootstrapping (Corresponds to the agent discovery phase of MIPv4)
    - Registration
    - Routing

MIPv6

- Mobile IPv6
  - Three phases
    - Bootstrapping (Corresponds to the agent discovery phase of MIPv4)
      - Static configuration
      - Anycast
        - » Packet routed to the nearest node of the anycast group
      - One HoA acquired, home link detection procedure performed to figure out if host is in its home domain

MIPv6

- Mobile IPv6
  - Three phases
    - Registration (when outside home domain)
      - Mobile Binding Update message sent by host to Home Agent
      - Parameters (HoA and CoA)

Mobile IPv6

- Mobile IPv6
  - Three phases
    - Routing
      - Bidirectional tunnel between HA and Host
        - » HA intercepts received packets and forward them to host
        - » Host sends all packets to HA which forwards them to the right destination
- Note: Unlike IPv4 triangular routing is not permitted (i.e. Host sent directly packets without going through HA, while all received packets go through home agent)

Other protocols: PMIPv6

- Proxy mobile IPv6 (PMIPv6)
  - Network based mobility management mechanism unlike the other mobile IP protocols that are host based.

Other protocols: PMIPv6

- Proxy mobile IPv6 (PMIPv6)
  - Differences between network based mobility and host based mobility:
    - Host based mobility
      - Host detects when it attaches to another networks and sends corresponding messages to home network
      - Requires mobility management in hosts

Other protocols: PMIPv6

- Proxy mobile IPv6 (PMIPv6)
  - Differences between network based mobility and host based mobility:
    - Network based mobility
      - An entity insides the network detects when host is attached to another network
      - The entity interacts with other entities in the network to ensure smooth mobility
      - No software mobility required in hosts

Other protocols: PMIPv6

- Proxy mobile IPv6 (PMIPv6)
  - Entities
    - Mobile Access Gateway (MAG)
      - Part of access network
      - Detects host when host attaches to a new network
    - Local Mobility Anchor (LMA)
      - » Act as home agent
  - MAG and LMA interact without host involvement to ensure smooth mobility management

Other protocols: DSMIPv6

- Dual Stack mobile IPv6 (DSMIPv6)
  - Enhancements to home agent to enable the support of mobile IPv4 in addition to the support of PMIPv6
    - Hosts may be IPv4 or IPv6
    - MAG support IPv4 and IPv6
  - Rather complex mechanisms

Other protocols: DSPMIPv6

- Dual Stack Proxy mobile IPv6 (DSPMIPv6)
  - Enhancements to LMA and MAG to enable the support of mobile IPv4 in addition to the support of PMIPv6
    - Hosts may be IPv4 or IPv6
    - MAG support IPv4 and IPv6
  - Rather complex mechanisms

Mobility management in EPC

- Preference for network based – management protocols although host based management protocols are allowed.

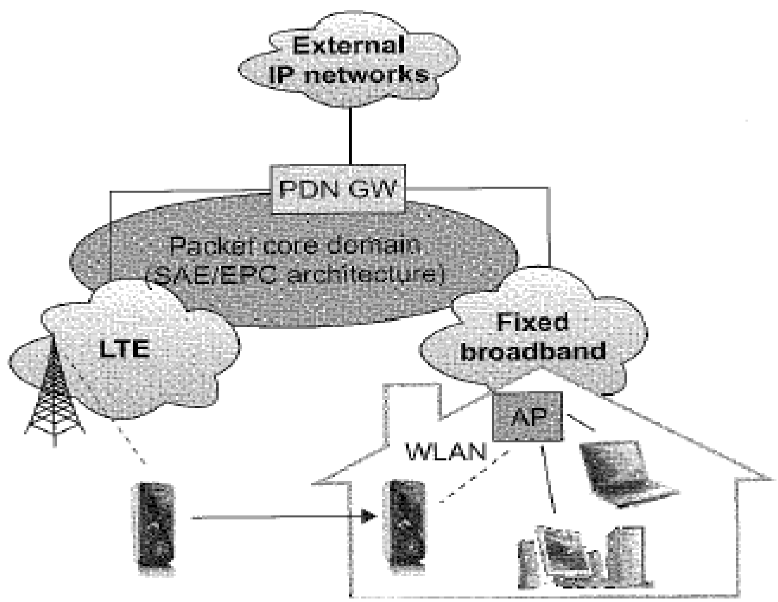
- DSMIPv6 and DSPMIPv6 are the future proof protocols

Mobility management in EPC

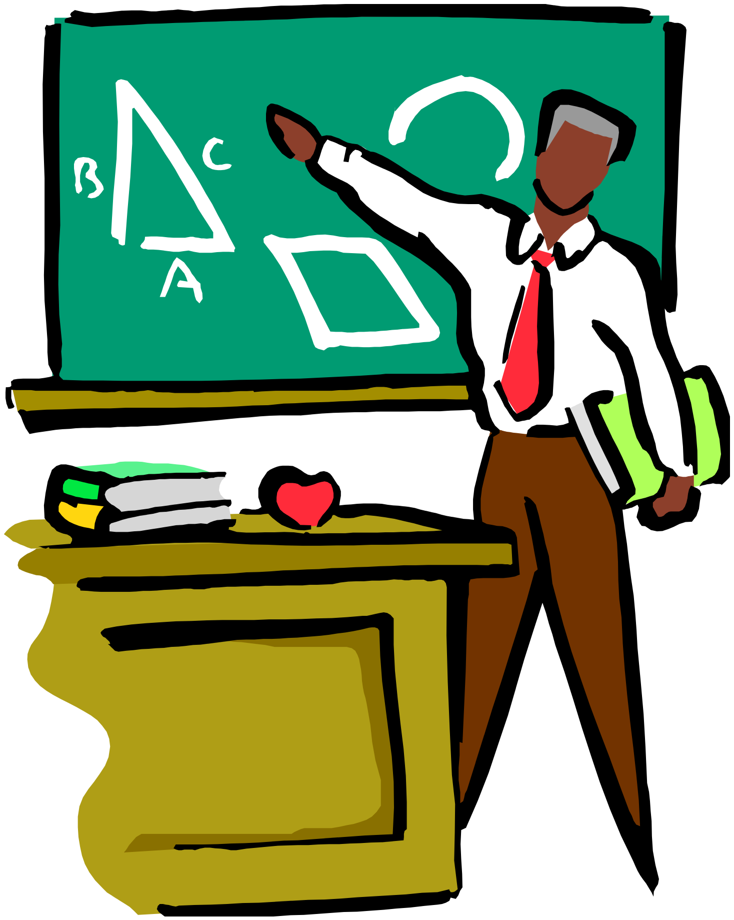
- Local Mobility Anchor (LMA) located on the PDN Gateway

Mobility management in EPC

- 1. Draw the full mobility sequence diagram when the user moves outdoors to indoors assuming that PMIPv6 is used.



QoS management in EPC



- Basics of QoS
- QoS concepts in EPC
- QoS mechanisms in EPC

Basics of QoS
Integrated Service Architecture - IntServ

Provide end to end QoS guarantees

Service classes

1. Guaranteed service

- Hard guarantee on delay and bandwidth
- Parameters provided by application
    - Peak rate
    - Packet size
    - Burst size

2. Controlled load

- Softer version of guaranteed service
- Guarantee that the QoS is equivalent to what it would have been if the network is not overloaded
- May not meet some of the hard requirements (e.g. delay)

Basics of QoS
Integrated Service Architecture - IntServ

Requirements on each router in the path:

1. Policing
2. Admission control
3. Classification
4. Queuing and scheduling

Basics of QoS
Resource Reservation Protocol - RSVP

Soft state signaling protocol used in InServ for uni-directional resource reservation

Rely on two messages:

PATH
- **Propagated from sender to receiver**

RESV
- **Propagated in the opposite direction**

Basics of QoS
Integrated Services Architecture - IntServ

Disadvantages

- Require major new software and firmware in routers
- Major overhead due to flows management
  - Flows are quite similar to telephone calls
    - Set up
    - Tear down

Basics of QoS
Differentiated services - DiffServ

Aim at addressing IntServ drawbacks by focusing on traffic aggregates instead of individual flows:

Scalability

- No need for router to maintain flow states
- No for refreshment messages due soft-state

Lack of general applicability

- Work even if every router in the path does not support it

No need for applications to support new APIs

Basics of QoS- Differentiated services - DiffServ

Fundamental principle: A code point – Differentiated service code point (DSCP) to tell routers how to treat a packet relatively to other packets

Per hop behaviour (PHB)

- Default
- Expedited forwarding
- Assured forwarding

Routers use PHB to drop/ prioritize packets on their output queue

QoS concepts in EPC (High Level)

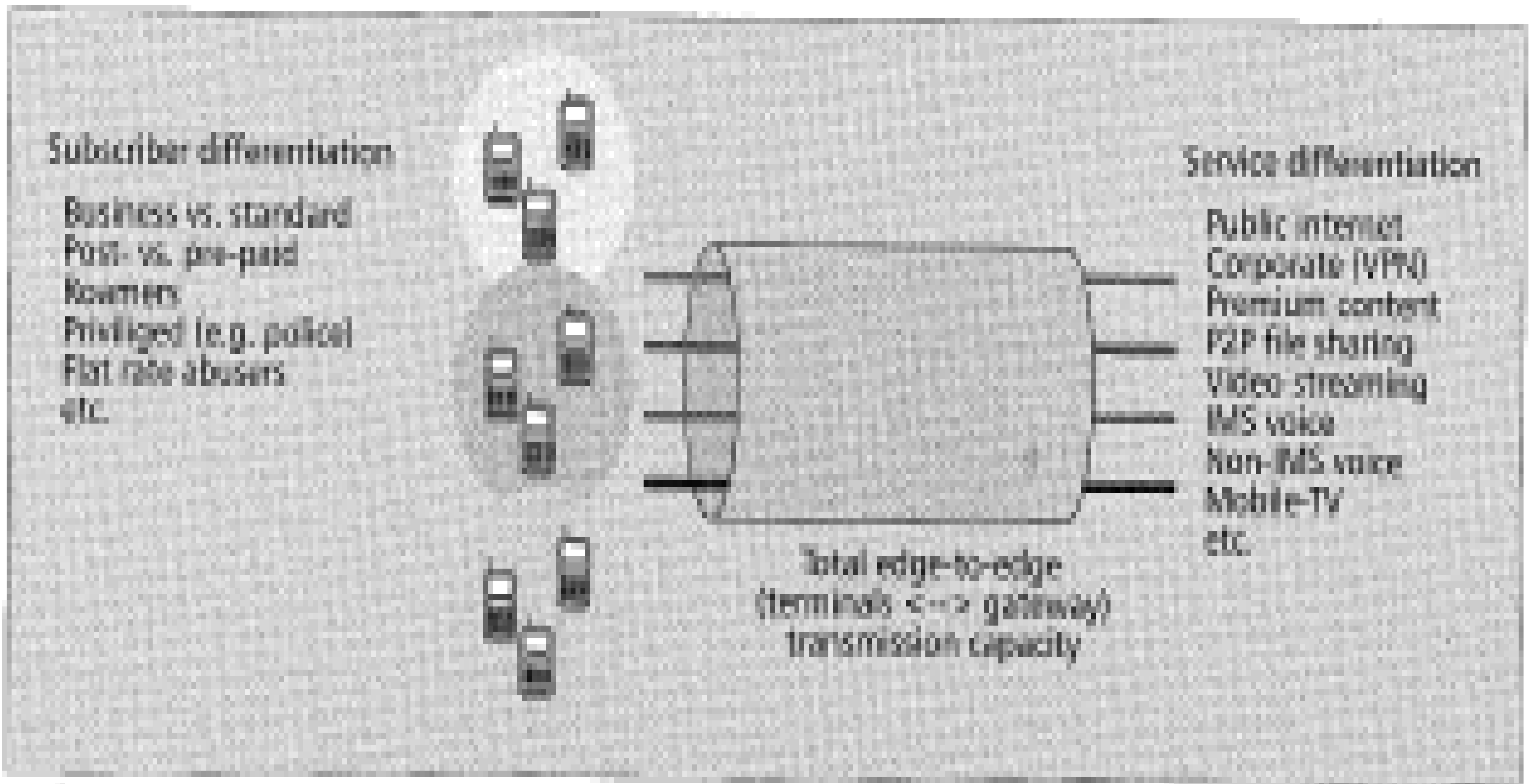
Key objective: Avoid the traditional over provisioning of telecommunication networks

Enable a cost effective differentiation between:

- Services
- Subscribers groups of a same service
- Subscribers and so on

QoS concepts in EPC (High Level)

From reference 2



High Level QoS concepts in EPC

Bearer:
packet flow that receives the same forwarding treatment

- Scheduling
- Queue management

Guaranteed bit rate (GBR) bearers

- Congestion related packet losses will not occur

Non Guaranteed bit rate (Non GBR) bearers

- Congestion related packet may occur

QoS mechanisms in EPC (High Level)

Key nodes:

- Gateways (Serving gateways and PDN gateways)
- PCRF

Other nodes may also be involved (e.g. LTE)

QoS mechanisms in EPC (High Level)

Examples of mechanisms

- Control plane signaling

  PCRF sends information to the gateways about how to handle packet flows from subscribers

- Bearer level function

  LTE may implementation admission control

- DSCP Level Function (DiffServ)

References

1. M. Olsson and al. SAE and the Evolved Packet Core, Wiley 2009 (Selected chapters)
2. IEEE Communications Magazine, Special issue on LTE / EPC, February 2009
3. B. Carpenter and K. Nichols, Differentiated Services in the Internet, Proceedings of the IEEE, September 2002