Delivery of Voice and Text Messages over LTE
• Two main approaches to the delivery of voice over LTE, both of which can be implemented in two ways

✓ 1st approach

- treat voice like any other data service
- deliver it using a voice over IP server that lies outside the LTE network
- can be implemented by
  ▶ a third party service provider
  ▶ a separate IP Multimedia Subsystem (IMS)
่าง 2nd approach

- connect LTE to the circuit switched (CS) domains of 2G and 3G, and to use their existing capabilities for placing voice calls

- can be implemented using two other techniques
  
  ‣ Circuit Switched Fallback (CSFB)
  
  ‣ Voice over LTE via Generic Access (VoLGA)

• Each of these four techniques can be adapted for the delivery of text messages, using either SMS or a proprietary messaging application
• Data applications supply most of the operators’ traffic, but voice supplies most of their revenue.

• Voice data rates are low (usually 64 kbps in the CS domains of 2G and 3G) and now only make up a small percentage of the total network traffic.

• Voice applications provide many valuable features to the user:
  ✓ notably supplementary services such as voicemail and call forwarding
  ✓ communication with fixed phones on PSTN
  ✓ the ability to place emergency calls
• Because of this, operators can still charge a large premium for **voice** services

✓ this premium is **falling**, but, **voice** still makes a disproportionate contribution to operator revenue

• A similar but more extreme situation applies in the case of **messaging services**, which make a **negligible** contribution to network traffic

* Premium：額外費用
* Disproportionate：不成比例
1. Third Party Voice over IP
2. The IP Multimedia Subsystem
3. Circuit Switched Fallback
4. VoLGA
1. Third Party Voice over IP

- The simplest technique is to provide a voice over IP (VoIP) service through a third party supplier such as Skype.
- The following figure shows the generic architecture that might typically be used for a voice service.
- A similar approach can be used for text messages.
Figure 16.2 Architecture of a generic third party VoIP system.
• The user sets up a call by
  ✓ exchanging VoIP signaling messages with an external VoIP server, and ultimately with another fixed or mobile phone
• During call setup
  ✓ VoIP server can send LTE signaling messages to the Policy and Charging Rules Function (PCRF), so as to request a dedicated EPS bearer to transport the call
• By doing this, the system can ensure a **good QoS** for the user, at least over the path between mobile and P-GW

• Using **media gateways (MGW)**
  ✓ the VoIP system can also convert IP packets to and from the data streams that are used by traditional CS networks
  ✓ this allows the user to make a call from a **VoIP device** to a 2G or 3G phone, or to a **land line**
Some technical issues

✓ if the user moves outside the region of LTE coverage, then the system may be able to handle the call using the 2G or 3G PS domains, or may be able to convert it to a traditional CS call

- if it does not support either of these approaches, then the call will have to be dropped

✓ Skype does not support emergency calls, so cannot yet be used to replace a traditional voice service
1. Third Party Voice over IP
2. The IP Multimedia Subsystem
3. Circuit Switched Fallback
4. VoLGA
2. The IP Multimedia Subsystem

- 2.1 IMS Architecture
- 2.2 IMS Procedures
- 2.3 SMS over IMS
2.1 IMS Architecture

- IP Multimedia Subsystem (IMS)

✓ a separate 3GPP network, which communicates with EPC and with the PS domains of UMTS and GSM so as to control real time IP multimedia services such as voice over IP

- IMS was originally specified in 3GPP Release 5
• Few 3G operators ever introduced because it is a complex system that requires significant investment from network operator

• IMS is very suitable for the delivery of voice and SMS over LTE and can be viewed as a sophisticated 3GPP version of the third party VoIP system

• The use of IMS is being promoted by the Voice over LTE (VoLTE) initiative of the GSM Association (GSMA), based on earlier work by an industrial collaboration known as One Voice

• It is likely to be the main long term solution for the delivery of voice over LTE
• **Worldwide VoLTE Status**

• 16 operators have launched **HD voice** (High-Definition voice, and also called Wideband Voice) service enabled by VoLTE in 7 countries (by April 9, 2015)

• 90 operators in 47 countries are investing in VoLTE deployments

• 186 smartphones (including carrier & frequency variants) support VoLTE (by GSA’s latest research.)
A simplified version of IMS and its relationship with LTE

✓ the most important components are Call Session Control Functions (CSCFs), of which there are three types

✓ Proxy CSCF (P-CSCF)

- the mobile’s first point of contact with IMS

- compresses the signaling messages that the mobile exchanges with the IMS so as to reduce their load on the LTE transport network

- secures those messages by encryption and integrity protection

- communicates with PCRF over the Rx interface, so as to guarantee the QoS of the IP multimedia streams
✓ **Serving CSCF (S-CSCF)**

- controls the mobile, in a similar way to an MME
- every mobile is registered with a S-CSCF, which sets up calls with other devices on the mobile’s behalf and which contacts the mobile if an incoming call arrives

✓ **Interrogating CSCF (I-CSCF)**

- the first point of contact for signaling messages that arrive from another IMS
Figure 16.3 Basic architecture of the IP multimedia subsystem.
• IMS Media Gateway (IM-MGW) and Media Gateway Control Function (MGCF)
  ✓ allow IMS to communicate with traditional CS networks such as PSTN
  ✓ IM-MGW converts VoIP streams to CS streams and back again
  ✓ MGCF carries out the same role for signaling messages, controls the IM-MGW and is itself controlled by S-CSCF

• Application Servers (ASs)
  ✓ provide the user with supplementary services such as voicemail

• Home Subscriber Server (HSS)
  ✓ a central database that is shared with EPC
• Session Initiation Protocol (SIP)
  ✓ the main IMS signaling protocol
  ✓ an IETF protocol widely used by other VoIP systems
  ✓ IMS network elements use SIP to
    - communicate with each other and with the mobile
    - carry out tasks such as registering the mobile and setting up a call
  ✓ SIP messages can contain embedded information written using Session Description Protocol (SDP)
    - SDP defines the properties of the media such as the requested data rate and the supported codecs
• The mobile

✓ identifies itself to IMS using a **private identity**, which acts in a similar way to the **IMSI**

✓ identifies itself to the **outside world** using one or more **public identities**, which act like **phone numbers** or **email addresses**

• These identities are stored in the **IP multimedia services identity module (ISIM)**, which is a **UICC (Universal Integrated Circuit Card)** application similar to the **USIM**
2.2 IMS Procedures

- The two most important IMS procedures are registration and call setup.
- If a mobile supports IMS, then it registers with the IMS after it has completed the attach procedure.
- Network operators typically use a separate Access Point Name (APN) for IMS, so the mobile begins by connecting to that APN using the UE requested PDN connectivity procedure.
The network responds by setting up a default EPS bearer for signaling communications with the IMS, most likely using QoS class identifier (QCI) 5.

<table>
<thead>
<tr>
<th>QCI Type</th>
<th>Packet error/loss rate</th>
<th>Packet delay budget (ms)</th>
<th>QCI Priority</th>
<th>Example Services</th>
</tr>
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<tbody>
<tr>
<td>GBR</td>
<td>$10^{-2}$</td>
<td>100</td>
<td>2</td>
<td>Conversational voice</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>150</td>
<td>4</td>
<td>Real-time video</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>50</td>
<td>3</td>
<td>Real-time games</td>
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<td>5</td>
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<td>100</td>
<td>1</td>
<td>IMS signalling</td>
</tr>
<tr>
<td></td>
<td>$10^{-6}$</td>
<td>300</td>
<td>6</td>
<td>Buffered video, TCP file transfers</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>100</td>
<td>7</td>
<td>Voice, real-time video, real-time games</td>
</tr>
<tr>
<td></td>
<td>$10^{-6}$</td>
<td>300</td>
<td>8</td>
<td>Buffered video, TCP file transfers</td>
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<tr>
<td></td>
<td>$10^{-6}$</td>
<td>300</td>
<td>9</td>
<td>Buffered video, TCP file transfers</td>
</tr>
</tbody>
</table>
• Using this bearer, the mobile sends a **SIP registration request** to the P-CSCF, which forwards it to a suitable S-CSCF.

• In the **registration procedure** that follows, the mobile and S-CSCF **authenticate** each other, and the mobile registers its **public identities** with S-CSCF.
• If an incoming call arrives, then the S-CSCF contacts the mobile by sending it a SIP signaling message over the EPS bearer

✓ if the mobile is in ECM-IDLE state, then the message triggers the LTE paging procedure

✓ the mobile moves back to ECM-CONNECTED by means of a service request and responds

ECM : EPS Connection Management
SDP : Session Description Protocol
• During call setup

✓ The two mobiles exchange SIP signaling messages with embedded SDP session descriptions, so as to set up the call and negotiate the voice codec that they will use

• At the same time, the two IMSs negotiate the QoS
In each IMS

✓ P-CSCF asks PCRF to supply a QoS that is appropriate for the selected codec

In response

✓ the P-GW sets up a dedicated EPS bearer that will carry the call

The IMS can also set up a call to a traditional CS network, using the media and signaling conversion functions provided by IM-MGW and MGCF
• Single Radio Voice Call Continuity (SRVCC)

✓ if a mobile moves outside the coverage area of LTE, then the network can use SRVCC technique to transfer the mobile from VoIP communications over IMS to traditional CS communications over GSM, UMTS or cdma2000 1xRTT

✓ SRVCC technique is based on inter-system handover procedures, but with extra steps to transfer the call without loss of service

• IMS offers full support for emergency calls over LTE from Release 9, using features such as null integrity protection algorithm

✓ integrity protection allows a device to detect modifications to the signaling messages that it receives, as a protection against problems such as man-in-the-middle attacks

✓ from Release 9, mobiles can use a null integrity protection algorithm for the sole purpose of making emergency voice calls without a UICC (Universal Integrated Circuit Card)
• Voice Call of LTE
  
  • VoLTE
    
    • All-IP base with IMS
    
    • target for virtually all operators
    
    • SRVCC (Single Radio Voice Call Continuity)
      
      • single-radio approach across technologies
      
      • designed for GSM/UMTS-LTE operators
    
  • CSFB (Circuit Switched Fallback)
    
    • an “interim” solution
    
    • limited service evolution
Step 1:
- No LTE coverage
- Voice call and SMS are over CS network
- Initial stage of LTE network

Step 2:
- LTE coverage is less than 3G network
- User services will be integrated into IMS-based service
- UE in cell edge or move out of LTE area, SRVCC will be performed for voice call continuity.

Step 3:
- For full LTE coverage.
- Final stage of LTE network
2.3 SMS over IMS

- IMS can also deliver SMS messages using **SMS over generic IP access technique**
- The only new component is the **IP short message gateway (IP-SM-GW)**, which acts as an interface between **IMS** and the network elements that handle **SMS messages**
Figure 16.4 Architecture used to deliver SMS messages over the IP multimedia subsystem.
• To transmit an SMS message

✓ the mobile embeds it into a **SIP signaling message** and sends it to **IMS**

✓ the **IP-SM-GW** extracts the embedded SMS message and sends it to **SMS interworking MSC (SMS-IWMSC)**

✓ this device then forwards the message to the **SMS service centre (SC)**, which stores the message for delivery to its destination

• The same sequence is used in reverse to deliver a message, except that the SMS-IWMSC is replaced by **SMS gateway MSC (SMS-GMSC)**
1. Third Party Voice over IP
2. The IP Multimedia Subsystem
3. Circuit Switched Fallback
4. VoLGA
3. Circuit Switched Fallback

- 3.1 Architecture
- 3.2 Combined EPS/IMSI Attach Procedure
- 3.3 Voice Call Setup
- 3.4 SMS over SGs
- 3.5 Circuit Switched Fallback to cdma2000 1xRTT
3.1 Architecture

• Many network operators are rolling out LTE before they roll out IMS

• Because of this, users may wish to place voice calls from LTE devices in the absence of IMS

• To deal with this possibility, 3GPP has standardized Circuit Switched (CS) FallBack as a possible interim approach
• Using CS fallback, a user can make voice calls by reverting to traditional CS communications over UMTS or GSM

• The architecture builds on the architecture for inter-operation with the 2G/3G PS domain, by supporting the CS domain as well
Figure 16.5 Circuit switched fallback architecture.
• In this architecture
  ✓ an MME can communicate with a MSC server that supports CS fallback, across SGs interface
  ✓ the signaling messages are written using the SGs application protocol (SGsAP)
  ✓ using these messages, a mobile can
    - **register** with an MSC server
    - **set up** a CS voice call
    - send or receive an **SMS message** using **SMS over SGs** technique
3.2 Combined EPS/IMSI Attach Procedure

- When a mobile switches on
  - It registers with a serving MME using the attach procedure
  - This procedure is modified for mobiles that support CS fallback, so as to register the mobile with an MSC server as well
Figure 11.4 Overview of the attach procedure.
Figure 16.6 Combined EPS/IMSI attach procedure.
• Step (1)

✓ In its attach request, the mobile uses **EPS attach type** to request a **combined EPS/IMSI attach**

✓ This indicates that it is configured for **CS fallback** and/or **SMS over SGs** and would like to **register** with an **MSC server**
• Step (2)

✓ The MME runs steps 3 to 16 of the attach procedure, which cover the steps required for identification and security, location updates and default bearer creation.

• Step (3)

✓ The MME then identifies a suitable MSC server and sends it an SGsAP Location Update Request.
• Step (4)

✓ In response, MSC server creates an association between mobile and MME and runs a location update procedure, in which it registers the mobile and updates the CS domain’s copy of the mobile’s location.

• Step (5-6)

✓ The MSC server then acknowledges the original request from the MME and the MME runs the remaining steps of the attach procedure.

✓ In its attach accept, the MME indicates whether the result was a combined EPS/IMSI attach, or an EPS only attach.
3.3 Voice Call Setup

- The figure shows the procedure for a mobile originated voice call using CS fallback

- Assumptions
  ✓ The mobile has previously registered with the CS domain using the combined EPS/IMSI attach and that the mobile is starting in RRC IDLE state
  ✓ The network can hand over the mobile’s PS services to the 2G/3G PS domain
Figure 16.7 Procedure for mobile originated call setup using circuit switched fallback, with the packet switched services handed over.
• The mobile starts with the usual procedures for random access and RRC connection establishment, and then writes an Extended Service Request

✓ This indicates that the mobile would like to place a voice call using CS fallback and includes the reason for the request, namely
  - Mobile originated call
  - Mobile terminated call
  - Emergency call

• Step (1-2)

✓ The mobile sends the message to BS as part of its RRC Connection Setup Complete

✓ The BS forwards the message to MME
• **Step (3)**
  ✓ The MME tells the BS to set up a signaling connection for the mobile in the usual way, but also sets a CS fallback indicator that requests a handover to the CS domain

• **Step (4-5)**
  ✓ The BS activates Access Stratum (AS) security and tells the mobile to move into ECM_CONNECTED state

• **Step (6-7)**
  ✓ The mobile’s response triggers an acknowledgement from BS to MME
• Step (8)

✓ As part of step 5, the BS also tells the mobile to measure the signals that it can receive from nearby UMTS and GSM cells

✓ The mobile makes the measurements and transmits a measurement report

• Step (9)

✓ Using the measurement report, the BS starts the procedure for handover from LTE to UMTS or GSM
• Step (10)
✓ Once the mobile is communicating with the target radio access network, it can contact the MSC server using a Connection Management (CM) Service Request that is written using the CS domain’s mobility management (MM) protocol

• Step (11)
✓ The mobile can then initiate the 2G/3G procedure for establishing a CS voice call

• Step (12)
✓ At the same time, the network can complete the handover by transferring the mobile’s EPS bearers to the 2G/3G PS domain, so that the user can continue any previous data sessions
✓ On completion of the call, the network can hand the mobile back to LTE
• If the network or mobile does not support PS handovers, then **CS fallback** is implemented using a different procedure, in which the BS **releases** the mobile’s **S1** connection and tells the mobile to carry out a **cell reselection** to 2G or 3G.

• As a result, the mobile’s **PS services** are **suspended** for the duration of the call.
• If a mobile terminated call arrives for the mobile, then the incoming signaling message arrives at the MSC server

✓ This notices that the mobile is registered with an MME and sends the MME an SGsAP paging request

✓ The MME runs the paging procedure and the mobile responds with an extended service request as before

✓ The call setup procedure then continues in a similar way
• If a mobile terminated call arrives while idle mode signaling reduction (ISR) is active, then the MSC server sends an SGsAP paging request to the MME in the same manner as before

✓ The MME contacts the SGSN, both devices page the mobile and the mobile responds in the usual way

✓ There are no direct communications between MSC server and SGSN, so the MSC server remains unaware of the use of ISR

Idle Mode Signaling Reduction (ISR)
* If the mobile is near the edge of the LTE coverage area, then it can easily bounce back and forth between cells that are using LTE and cells that are using UMTS or GSM. There is then a risk that the mobile will execute a large number of routing and tracking area updates, leading to excessive signaling.
* ISR technique behaves very like the registration of a mobile in multiple tracking areas. When using ISR, the network can simultaneously register the mobile in a routing area that is served by an S3-based SGSN and in one or more tracking areas that are served by an MME. The mobile can then freely reselect between cells that are using the three radio access technologies and only has to inform the network if it moves into a routing or tracking area in which it is not currently registered.
• CS fallback only requires a few enhancements to the system and is likely to be the main interim solution for the delivery of voice over LTE

• Several drawbacks

✓ Firstly, the mobile can only use the technique if it is simultaneously in the coverage area of LTE and a 2G or 3G cell
✓ Secondly, the procedure involves delays of a few seconds while the mobile makes its measurements and the network hands it over
✓ Thirdly, inter-system handovers have traditionally been one of the least reliable aspects of a mobile telecommunication system
  - If this unreliability is repeated in the case of LTE, then CS fallback will result in many dropped calls

• Overall, the resulting service degradation makes it doubtful whether CS fallback is actually an acceptable solution
3.4 SMS over SGs

- Similar ideas for the delivery of SMS messages
- The mobile does not have to hand over to a 2G or 3G network before sending or receiving a message
- Instead, the network uses SMS over SGs technique to deliver SMS messages by embedding them into signaling messages between MME and MSC server
Figure 16.8 Architecture for SMS over SGs.
• **SMS over SGs technique**

✓ the mobile **registers** with the **CS domain** using the combined **EPS/IMSI attach** procedure

✓ it can then send an **SMS message** to **MME**, by embedding it into an **Uplink NAS transport** message

✓ the **MME** can then forward the SMS message to the **MSC server**, by embedding it into an **SGsAP Uplink Unitdata message**

✓ from there, the SMS message is passed to the **SMS interworking MSC** and the **service center** in the usual way

**NAS**: Non Access Stratum
• If a **mobile terminated SMS** reaches the **MSC server** while the mobile is in ECM-IDLE state

✓ then the MSC server alerts the MME using an **SGsAP Paging Request**

✓ this triggers the **paging** procedure and the mobile replies by initiating a **service request**

✓ MME can then retrieve the **SMS message** from the MSC server and can deliver it to the mobile

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**ECM**: EPS Connection Management  
**SGsAP**: SGs Application Protocol
4.5 Circuit Switched Fallback to cdma2000 1xRTT

- The 3GPP specifications also support CS fallback to cdma2000 1xRTT networks
Figure 16.9 Architecture for circuit switched fallback to cdma2000 1xRTT.
• After attaching to LTE
  ✓ the mobile **preregisters** with a cdma2000 **1xRTT MSC**, using 1xRTT signaling messages that are transported across the **S102** interface

• If the user wishes to **place a voice call** later on
  ✓ the mobile sends an **extended service request** to the MME
  ✓ MME tells the BS to initiate a **handover** to cdma2000 **1xRTT**
• If an **incoming call** arrives for the mobile
  ✓ the 1xRTT MSC sends the mobile a **paging message** across the **S102** interface
  ✓ this triggers an **extended service request** from the mobile and the **call setup** procedure
  ✓ the mobile can also send and receive **SMS messages**, by **tunneling** them to and from the 1xRTT MSC over S102
1. Third Party Voice over IP
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4. VoLGA

- Voice over LTE via generic access (VoLGA)
  - ✓ another technique for delivering voice calls to LTE devices using the existing capabilities of the 2G/3G CS domain
  - ✓ through VoLGA, a mobile can reach the 2G/3G core network through a generic access network such as a WLAN
- VoLGA architecture connects P-GW to 2G/3G CS domain through a VoLGA Access Network Controller (VANC)
• From the viewpoint of **P-GW**, VANC looks like any other **server** in the **outside world**

• From the viewpoint of **CS domain**, VANC looks like a **generic radio access network**

• As a result, LTE system can impersonate the behavior of a **generic radio access network** and can give the mobile access to the **services** of the 2G/3G CS domain

• VoLGA has found **less support** from the industry than the other approaches, and appears **unlikely to be widely adopted**
Figure 16.10 VoLGA architecture.