Network Identifiers Overview

Public Safety Communications Research

Emil Olbrich

"Those that fail to learn from history, are doomed to repeat it."

— Winston S. Churchill

Decision Timeline

- June 2009 – Public Safety Chooses Long Term Evolution (LTE) as the technology choice for a nationwide broadband network
  - APCO & NENA endorse endorse LTE
  - National Public Safety Telecommunications Council (NPSTC) vote to endorse LTE - *Works starts on NPSTC Broadband Task Force (BBTF)
- January 2010 – FCC adopts NPRM & selects LTE as technology platform
- May 2010 – FCC approves 21 initial waivers for early deployment of 700 MHz PS LTE
- June 2010 – Round 2 of NTIA Broadband Technology Opportunities Program (BTOP) opened up to waivers
- July 2010 – NTIA awards over $300 MUSD to 7 of 21 waivers
- June 2011 – State of Texas granted waiver by FCC

PSCR

Network ID Timeline

- July 2009 – PSCR hosts face-to-face meeting in Boulder to finalize NPSTC BBTF report.
  - PLMN ID framework, Roaming & Clearing discussed for first time regarding PS LTE
- August 2009 – NPSTC BBTF released.
  - Section 6.3.1 discusses potential PLMN ID issues & structures
    - *NOTE: LTE was not yet commercially deployed in the United States, little was know about how the network would be built out, waivers hadn't been yet assigned, D-Block unsettled, funding unknown… etc.*

NPSTC BBTF Report

- ## 6.3.1 System Identifiers
  - Public safety LTE systems must comply with 3GPP standards and therefore they must be assigned a PLMN ID. Since PLMN IDs are a limited resource shared by all 3GPP wireless networks worldwide, the use of PLMN IDs should be effectively managed. The Technology Working group has considered two alternatives for assignment of PLMN IDs:
    1. **Single PLMN id shared by all public safety networks**
    2. Individual PLMN id for each public safety network
  - The following are the recommendations for System Identifiers:
    1. A common schema should be used to identify public safety users and regional networks (intra-system – category 1 roaming).
    2. Per the definition, a PLMN must be operated by an administration or by a recognized operating agency (ROA).
       a. For either single PLMN or individual PLMNs, the PSBL and/or the NPSTC Governance Working Group must determine the structure of the ROA.

PSCR

3. **The PSST board with advice from the advisory group must determine the long term strategy for the organization of Public Safety PLMNs and have it apply to the initial waiver requesters.**

4. **The PSST board with advice from the advisory group will determine with the IOC, the recommended number of PLMN IDs**
   a. **If the PSST becomes the overall operator for regional public safety 700 MHz LTE networks, then a single PLMN ID should be adopted**
   b. **If individual PLMN IDs are chosen to be assigned to regional networks**
      I. **PLMN ID regions should be based upon some form of geographic, population and demographic determination.**
      II. **Logically each network will be organized and operated as an independent PLMN.**
      III. **The number of PLMN IDs allocated will be the determination of the IOC but the actual amount recommended should be less than 100 IDs**

5. **PSBL will apply for dedicated PLMN ID(s) (MCC/MNC/HNI) from the IOC**
   a. **Use an existing MCC as determined by ATIS and IOC.**
   b. **Recommend that the PSST investigate and potentially ask for a dedicated MCC for public safety networks.**

6. **USIM is provisioned by the home network administrator with**
   a. **Home IMSI (HPLMN)**
   b. **Prioritized list of permitted VPLMNs**
   c. **Forbidden PLMNs list**

PSCR NAWG

- Spring & Summer of 2010 PSCR hosted a series of Network Architecture Working Group Meetings (NAWG)
  - June 8, 2010 PLMN ID architecture proposals sought
  - June 29, 2010 NAWG meeting #2 held where LTE IDs were first discussed
    - APN Naming convention
    - plmn-IdentityList
    - cellReservedForOperatorUse
    - trackingAreaCode
    - cellBarred
    - intraFreqReselection
    - selectedPLMN-Identity
    - registeredMME
    - mmegi

NAWG Proposal

- ## Initial proposal from PSCR was called the "hybrid approach"
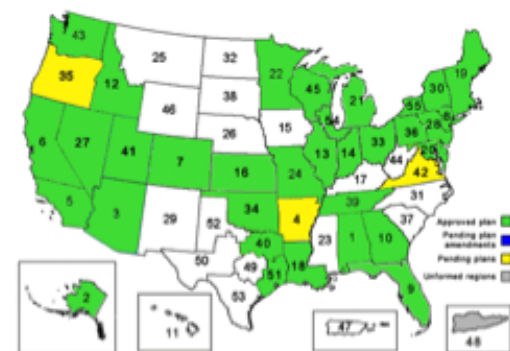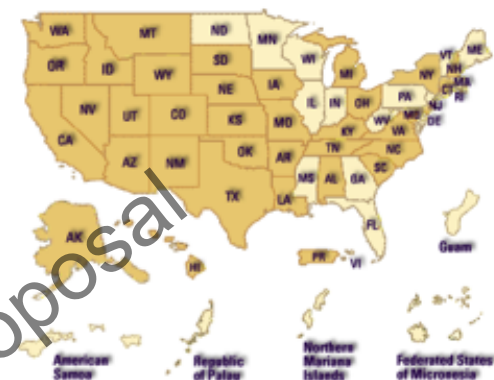
  - **Essentially based on a "network of networks approach"**
  - **Relied heavily on to be yet developed "intra-network roaming**
  - **Seen as an alternative to individual waiver PLMNs**

- ATIS IOC has tentatively approved PLMN usage plan from PSCR – Potentially assign MCC to PS and assign ~60 PLMN IDs initially and leave the remaining ~39 for growth.
    - eNodeB transmits minimum two (2) PLMN IDs (maximum of 6)
    - National PLMN ID - Use of a single nationwide network in which everyone is treated equally as a roamer and would be used to identify users that have no HPLMN such as Federal users. E.g. Blanket or Umbrella PLMN
    - Allocate a HPLMN ID per state and territory or RPC area (see maps on left) – will consume 55 to 56 PLMN IDs
    - Potentially assign a PLMN ID to a few large metropolitan areas that have their own LTE network and would own a PLMN id (less than 10?).
- PS eNB would broadcast HPLMN and National PLMN and could support commercial PLMN as agreed upon.
- Ue/USIM whitelist would contain National PLMN and HPLMN – would also contain approved commercial network PLMNs

Note that having a PLMN ID does not necessitate that each of these regions have or require their own core network. Multiple regions could share a packet core to reduce the cost and alleviate the region from the management aspects associated with the EPC. EPC functions would be logically separated to the end user

- **Proposed solution had not been worked out in technical detail – just high level functionality. i.e. could take years to standardize**

ATIS IOC

- Alliance for Telecommunications Industry Solutions International Mobile Subscriber Identity Oversight Council (ATIS IOC) was initially contacted in May 2010 by PSCR to discuss public safety use of the PLMN
- IOC is responsible for overseeing the management of IMSI codes that have been assigned to the United States and its possessions as authorized by the U.S. Department of State since 1996 http://www.atis.org/ioc/
  - PSCR and other interested parties invited to IOC meetings in Sept & Oct 2010 to discuss issues related to public safety use of the PLMN
  - Multiple tiered strategy setup with IOC & FCC to address PLMN ID issues
    - Change IOC rules to allow public safety to apply for a PLMN (**see following page**)
    - Get permission to use test PLMN ID for demo network
      - » **IOC now allows PSCR and PS to use test ID**
    - Allocate another test PLMN ID for multi-PLMN ID testing
      - » **310-014 and 311-400 both now allocated for testing purposes**

PSCR

IOC Guideline Changes

- November 2010 - PSCR and MSI develop draft language for changes to section 6, CRITERIA FOR HNI ASSIGNMENT, in the IMSI Guidelines - http://www.atis.org/ioc/Docs/Guidelines/IMSI-Guidelines-v12.doc

  - December 2010 – Changes adopted in current v12 Guidelines (section 6 CRITERIA FOR HNI ASSIGNMENT – excerpts below)

    - The HNI applicant must be, and certify that it is, a public network operator (commercial or government), or an authorized agent operating on behalf of a public network operator, offering mobility services in the United States with a need to roam onto/from commercial networks, or that it is a provider of a service profile management system (e.g. Home Location Register [HLR], Home Authentication, Authorization, and Accounting [AAA], or Home Subscriber System [HSS]) based in the United States for end user devices that can access public networks in the United States.

    - The applicant/assignee of an HNI must have and provide evidence of authorization, if required, from the appropriate federal, state or local regulatory authorities to operate in the area in which it intends to provide mobility services.

    - At least one radio interface protocol used by the network equipment or end user devices of the Applicant must be from the following list of protocols known to require IMSI for identification and signaling:....Long Term Evolution (LTE) protocols including LTE Advanced.

Administration Stance

- May 2011 - NTIA filed comments on behalf of the Administration, DOC, DOJ & DHS to the FCC Service Rules for the 698-746, 747-762 and 777-792 MHz Bands
  - Implementing a Nationwide, Broadband, Interoperable Public Safety Network in the 700 MHz Band
  - Amendment of Part 90 of the Commission's Rules
    - Intra-public safety network roaming ceases to be a concern in a nationwide network, but remains a significant problem and cause of inefficiencies in a series of regional networks. The Corporation should require only a single Public Land Mobile Network (PLMN) identifier for the purpose of facilitating roaming among public safety users of a single nationwide public safety broadband network and commercial networks;

PSCR

Stakeholder Support

- Public Safety organizations filed public statements in support of a nationwide network approach using a single PLMN ID
    - March 2011 – NPSTC board supports single PLMN ID usage
    - September 2011 – APCO board supports single PLMN ID usage

PSCR

Industry Support

- August 2011 - ATIS WTSC send an industry support letter to the IOC for a single PLMN for public safety
  - Supported by multiple companies

Alcatel-Lucent	Nokia Siemens Networks
AT&T	One2Many
Aviat Networks	Public Safety Canada
CenturyLink	Qualcomm Inc.
Cisco Systems	Research in Motion
Clearwire	Rogers Wireless Inc.
Department of Commerce	Sprint
Department of Defense	T-Mobile USA Inc.
Ericsson	Telcordia Technologies
FBI ESTS	TeleCommunications Systems, Inc.
Huawei Technologies	Tellabs Operations, Inc.
Intel	TruePosition, Inc.
InterDigital Communications	Union Telephone Company
Kineto Wireless, Inc.	Velleros
MetroPCS	Verizon Communications
National Communications System	

NOTE: Metro PCS, Verizon Wireless, AT&T have commercially launched LTE networks in the United States using a single PLMN ID

Network ID Study Item Group

- June 2011 – PSCR launches Network Identifiers Study Item Group
  - Scope of work document developed to encompass single PLMN ID network architecture for PS and test in PSCR demo network
  - August 2011
    - 1st Meeting on scope of work discussion and timeline setup to develop nationwide framework by end of 2011
    - 2nd Meeting at APCO conference working on further requirements for all Network IDs – PSCR makes initial determination of list of managed LTE network IDs
  - October 2011 – 3rd meeting held to go through all submittals and latest nationwide approach
  - Nov 2011 – 4th meeting held focusing on imminent PS deployments
    - Face-to-Face meeting
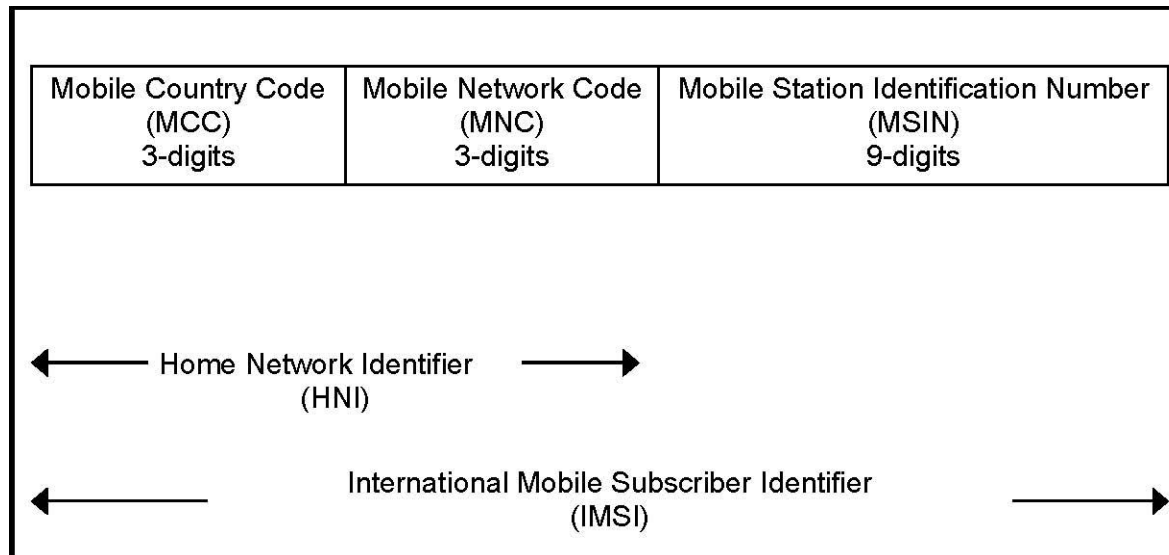
Network ID Study Item Scope of Work

- Develop network identifier requirements for a single nationwide PLMN for public safety (700 MHz) and the support test cases to evaluate the requirements
  - Multiple jurisdictions with local control of infrastructure
  - Multiple regional redundant EPC data centers
  - Multiple eNB and EPC vendors
  - Evaluate Network ID usage and deployment options
    - Consider how to integrate waiver recipient networks into a national network
    - Define technical requirements and dependencies for determining/choosing network identifiers that can be used by TBD governance organization
- In Phase 1, consider:
  - Single band (PSBL Band 14)
  - Common APN naming scheme with local/regional flexibility
  - "Splitting" network identifiers under one PLMN
  - Solutions for user identity to HSS resolution
  - DNS and sub-domain naming between EPC data centers
- In Phase 2 consider:
  - Commercial carrier roaming; regional subscription zones
  - Inter-PLMN handovers (intra-RAT, inter-RAT)
  - ENUM, IMS, IPX interconnect options, etc.

PSCR

Network ID Study Item Deliverables

1. Focus initial phase of study on 33 network identifiers (21 of 33 are "Permanent")

   a. Validate feasibility of single PLMN ID for multiple jurisdictions nationwide; show model architecture of a nationwide network & use cases

   b. Identify key issues to be solved (e.g., user ID to HSS resolution, subdomains, commercial roaming, etc.)

   c. Identify which parameters need or should be "managed"

2. Develop use cases & requirements for key issues (e.g., split IMSIs, TAIs, Diameter proxy agent, O&M, etc.)

3. Identify relevant 3GPP and GSMA technical specification references and requirements.

   a. Determine what GSMA IR.21 information is required for carrier roaming – may feed directly into Roaming and Clearing Study Item

4. During first phase, identify additional network identifiers for second phase of study (e.g., ENUM, IMS, regional subscription zones, base station identity & color code, etc.)

PSCR

What is a PLMN?

- PLMN – Public Land Mobile Network
  - PLMN = Home Network Identifier (HNI) ~ Public Mobile Network (PMN)
  - Consists of a Mobile Country Code and Mobile Network Code

Mobile Country Code (MCC) 3-digits	Mobile Network Code (MNC) 3-digits	Mobile Station Identification Number (MSIN) 9-digits

← Home Network Identifier (HNI) →

← International Mobile Subscriber Identifier (IMSI) →

What is the PLMN used for?

- The function of the MCC is to identify the domiciliary country of a mobile terminal/user. By analyzing the MCC, a visited network can determine the country from which the mobile terminal/user originated and in which its home network resides.

- The function of the MNC is to identify the home network, within the country associated with the MCC, of the visiting mobile terminal/user. The visited network uses the MCC-MNC combination to identify and query the home network of the visiting mobile terminal/user that is requesting service.

*excerpt from IOC Guidelines

What is an IMSI?

- Determination of the mobile terminal's/user's home network,

- Mobile terminal/user identification when information about a specific mobile terminal/user is to be exchanged between visited and home networks,

- Mobile station identification on the radio control path for registering a mobile station in a visited wireless network,

- Mobile station identification for signaling on the radio control path,

- Identification of the mobile terminal/user to allow for charging and billing of visiting mobile terminals/users, and

- Subscription management, i.e., retrieving, providing, changing, and updating subscription data for a specific mobile terminal/user. *excerpt from IOC Guidelines*

PSCR

Network IDs Review

- Study item determined five initial identifiers (with additional sub-identifiers) that require national management

  1. IMSI - – includes PLMN (MCC + MNC) & MSIN
  2. TAI – Tracking area ID
  3. GUTI – Globally Unique Temporary UE ID
  4. ECGI - E-UTRAN Cell Global ID
  5. APN – Access Point Name

- Further research showed that some "permanent" LTE (non-IMS) network identifiers need to be managed or coordinated at some level. This includes:

MMEI	MMEC	MMEGI	IMEI/SV*	TAC
ECI	Global eNB ID	eNB ID	IMEI*	HA-APN
GUMMEI	TAI List	P-GW ID	MSISDN**	*MBMS

*Partially out of scope
**Includes eNUM and all numbering plan info

PSCR

IMSI

IMSI - International Mobile Subscriber Identity

PLMN ID

MCC 3 digits	MNC 2-3 digits	MSIN 9-10 digits

IMSI
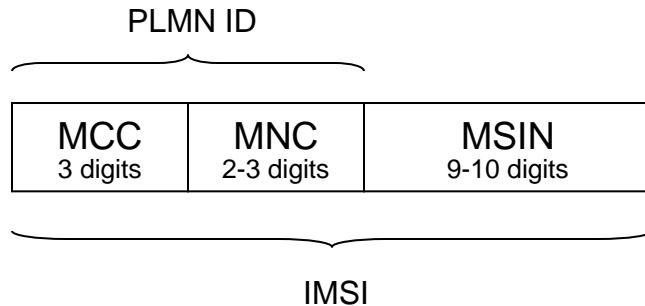
- PLMN ID - Public Land Mobile Network Identifier
- MCC - Mobile Country Code
- MNC - Mobile Network Code
- MSIN - Mobile Subscriber Identification Number

- ## Single PLMN ID for all of Public Safety
  - E.g MCC=312 MNC=911 PLMN/HNI=312911
- ## MSIN assumption is 9 digits available for use (~1 Billion device IDs)
  - Approx. 2~5 million PS first responders (Roughly 5% of population)
  - Approx. 24 million potential devices (1st & 2nd responders, M2M, redundancy, future growth... etc.)
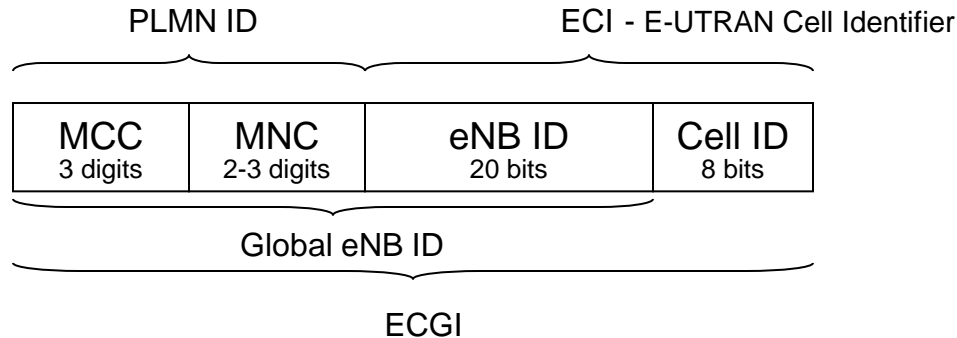
RAN Identifiers

- Several LTE specific identifiers can be used by the public safety network to delineate network and/or jurisdictional boundaries – though this is not their original intended use.
  - Typically used to identify individual cells in the network, O&M and SON, define paging areas… etc.

| ECGI	E-UTRAN Cell Global Identifier	Unique cell ID (globally)	PLMN+ECI <= 52 bits
ECI	E-UTRAN Cell Identifier	Unique cell ID (in PLMN)	ECI(28bits)=eNB ID+Cell ID
Global eNB ID	Global eNodeB Identifier	Unique eNodeB ID (globally)	PLMN+eNB ID
eNB ID	eNodeB Identifier	Unique eNB (in PLMN)	20 bits
Cell ID	eNB Cell ID	Unique for each sector of a cell/eNB	8 bits
TAI	Tracking Area Identity	Unique tracking area (globally)	PLMN + TAC
TAC	Tracking Area Code	Unique tracking area (in PLMN) Per cell in eNB	16 bits
TAI List	Tracking Area Identity List	UE can move to cells included in TAI List w/o location update	variable length

ECGI Allocation

ECGI - E-UTRAN Cell Global Identifier

PLMN ID   ECI - E-UTRAN Cell Identifier

MCC 3 digits	MNC 2-3 digits	eNB ID 20 bits	Cell ID 8 bits

Global eNB ID

ECGI

- **ECGI required at for eNB commissioning**
  - **eNB ID used to identify individual eNodeB (cell site)**
    - **20 bits = 1,048,576 available unique eNB IDs**
    - **Every eNB must be identified**
  - **Use Cell ID 01-06 range to define specific sector of eNB ID**
    - **Append 8 bits to right of eNB ID e.g. alpha sector = 01, beta sector = 02… etc.**
      - **eNB = 186C7, ECI = 186C701 (alpha sector)**
    - **Every sector must be identified within a cell**
  - *R10 requires a FQDN for the Global eNB ID = enb<eNodeB-ID>.enb.epc.mnc<MNC>.mcc<MCC>.3gppnetwork.org*
    - **Example FQDN = enb186701.enb.epc.mnc911.mcc312.3gppnetwork.org**

Tracking Area IDs

TAI - Tracking Area Identity

PLMN ID

| MCC 3 digits	MNC 2-3 digits	TAC 16 bits

TAI
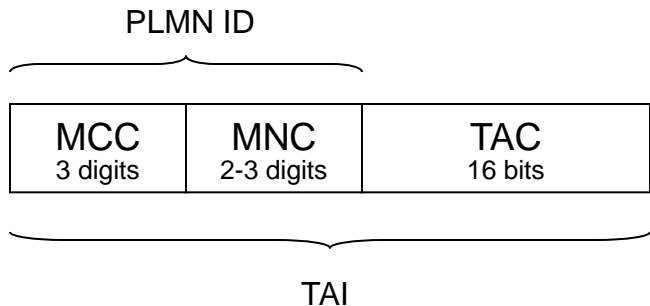
- ✧ TAC = Tracking Area Code, unique in PLMN, indicates per cell the tracking area for an eNB, 16 bits (FFFF)
  - ✧ eNB cell (sector) can only be part of one TAC **e.g. multiple eNodeBs are part of a TAC**
- ✧ TAI – Tracking Area Identity, globally unique, identifies tracking areas, 32 bits (FFFFFFFF)
- ✧ TAI List – Allows UE to move to cells in list without location update, globally unique

- TAI provisioned in eNB at commissioning - Necessary for Tracking Area Update (TAU) e.g. handover (active & idle)
  - TAI needs to be managed & engineered properly
    - *Too large may lead to excessive overhead messaging to cells*
    - *Too small may lead to unnecessary retries of messaging to cells*
  - TAI List used in MME
    - UE only uses first 16 TAI in TAI List
      - TAI List is important for mobility *if* location updates aren't working or updating in the MME properly
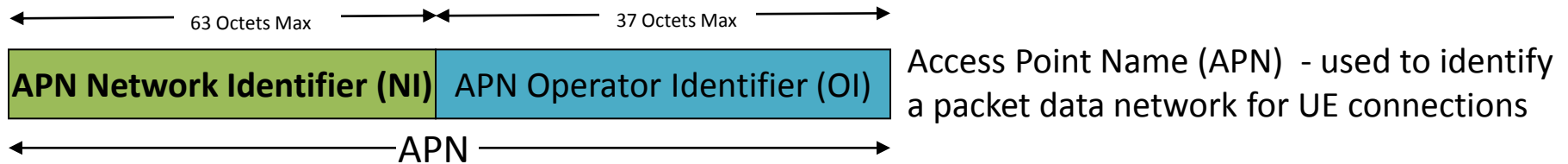
PSCR

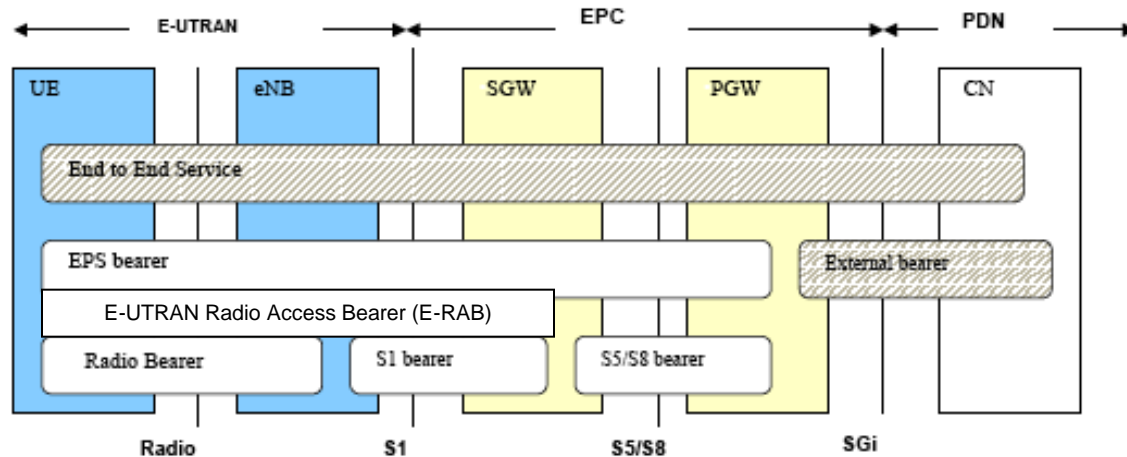GUTI- Globally Unique Temporary UE Identity
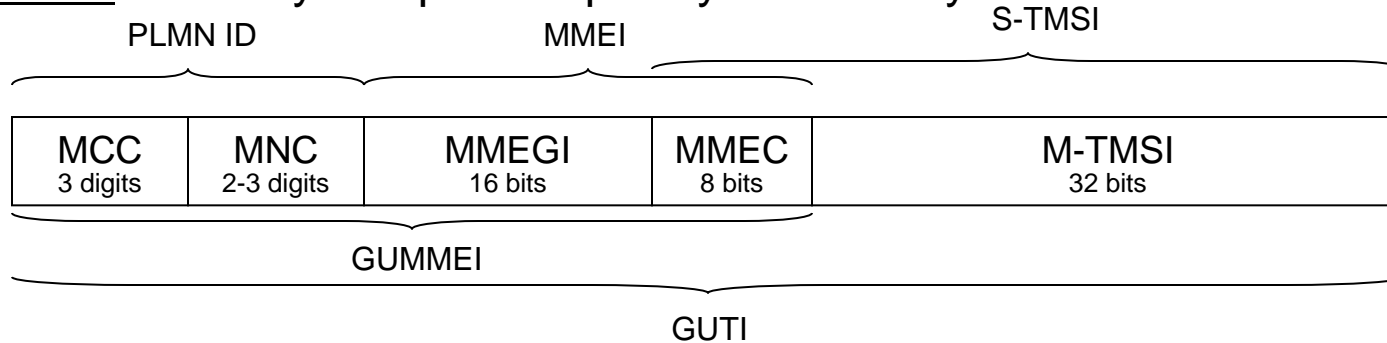
- **Unique Identifiers – need to be managed & coordinated nationally**
  - MMEC – MME Code that is unique in a MME Group, 8 bits (FF), individual MME identifier
  - MMEGI – MME Group ID, 16 bits (FFFF) used in pooling of MMEs
    - PSCR Concerned about integration of waiver networks into nationwide network e.g. MME Pooling

- **Derived Identifiers**
  - MMEI – MME ID unique within a PLMN = MMEGI + MMEC, 24 bits
  - GUMMEI – Globally Unique MME ID = PLMN + MMEI, 48 bits
  - GUTI – Globally Unique Temporary UE ID = GUMMEI + M-TMSI, 80 bits

APN Identifier

63 Octets Max | 37 Octets Max

APN Network Identifier (NI) | APN Operator Identifier (OI)

Access Point Name (APN) - used to identify a packet data network for UE connections

APN

- Unique Identifiers – need to be managed & coordinated nationally
  - Identifies the Packet Data Network (PDN) that the UE via the P-GW will connect to for a specific application

- APN consists of two parts
  - Network Identifier (NI) – network that you are connecting to
    - Typically use multiple APNs to utilize different services
    - e.g. VZW vzwims - voice and video, vzwadmin – test, vzwinternet – internet & browsing, vzwapp – internal VZW apps
  - Operator Identifier (OI) – consists of the PLMN ID (e.g. PLMN = 312911)
    - APN OI = mnc911.mcc312.gprs (resolves to 3gppnetwork.org

LTE network diagram showing the following annotations:

- **HSS** (in RED):
  - IMSI
  - UE IP (static)
  - PGW ID (static)
  - PDN ID (APN)

- **MME** (in RED):
  - GUMMEI
  - TAI List rule

- **eNB** (in RED):
  - eNB ID
  - ECGI
  - MMEI
  - TAI

- **UE / car** (in RED):
  - IMSI
  - IMEI

- **PGW** (in RED):
  - PGW ID
  - IP Pool (dynamic IP alloc)

Network elements: HSS, MME, DNS, PCRF, eNB, SGW, PGW

Cloud connections:
- Agency-A Apps — APN(a)
- Internet — APN(i)
- Agency-B Apps — APN(b)

Bearer diagram: E-UTRAN | EPC | PDN
- UE, eNB, SGW, PGW, CN
- End to End Service
- EPS bearer, External bearer
- E-UTRAN Radio Access Bearer (E-RAB)
- Radio Bearer, S1 bearer, S5/S8 bearer
- Radio, S1, S5/S8, SGi

LEGEND:

eNB - evolved Node B

MME - Mobility Mgmt Entity

HSS - Home Subscriber Server

DNS - Domain Name Server

SGW - Serving Gateway

PGW - Packet Data Network Gateway

PCRF - Policy & Charging Rules Function

RED - Permanent (provisioned)

27

For Additional Information:
http://www.pscr.gov

Emil Olbrich
emil.olbrich@nist.gov

Nationwide Backup Slides

Distributed Core Network Elements

- **Some functions of the core network will be centralized and others will be distributed. For example:**
  - The database that contains all of the users, policy control for QoS on the system may be centralized in functionality (geographically redundant). e.g. HSS, SLF, PCRF
  - Mobility management might be done locally/regionally (East, Central, West). e.g MME
  - The components that provide access to the Internet or require high speed access might be at a sub-regional level (i.e. state or sub-state) to reduce transport costs. e.g. P-GW, S-GW

Nationwide Network Architecture

- **Network Architecture would be managed nationwide and have an architected core network with:**
  - A nationwide RAN utilizing one PLMN-ID (network identifier)
    - *Does not imply a single vendor*
  - Centrally managed subscriber database, authentication, security – with local control for provisioning/management as required
- **Interoperability of multiple vendors equipment within the nationwide network would be tested before network/equipment deployment**
- **No roaming between public safety agencies within the nationwide PSBN (all in the same network)**
- **Roaming in this context means PSBN users accessing commercial networks (3G/4G)**
- **Governance would mean a single nationwide network operator with some local flexibility and regional operations**

PSCR