LTE Design and Deployment Strategies

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Right Acronym for LTE

LTE	Long Term Employment
	Long Term Evolution
	Life Time Employment

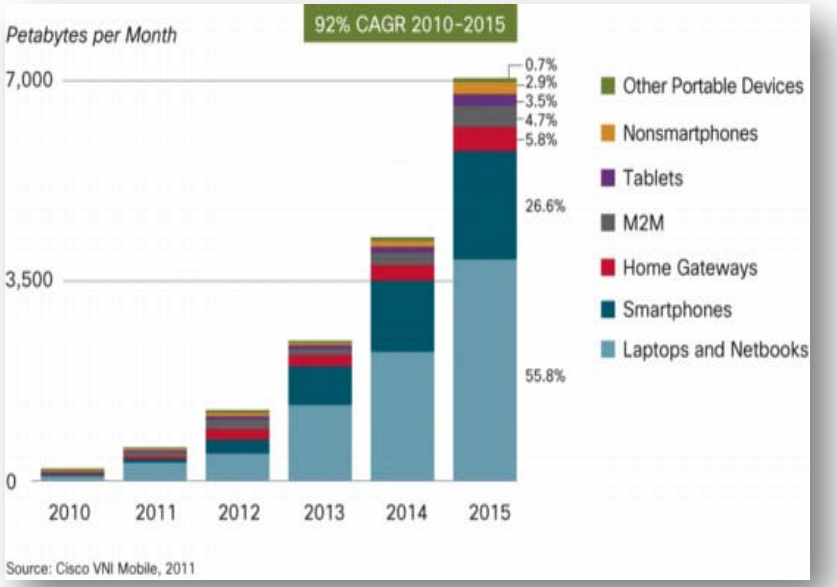
Agenda

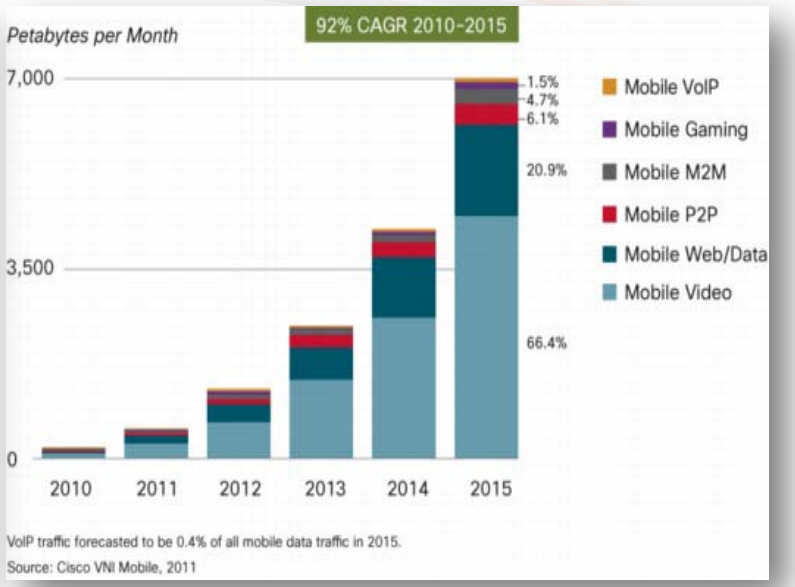
- **Mobile Broadband Dynamics**
- Mobile Network Evolution
- LTE Architecture Framework
- LTE Design Strategies
  - Latency & Delay
  - IP Planning
  - MME, SGW, PGW, DNS
  - Transport Planning – Backhaul, MPLS Core
  - LTE Security
- LTE Deployment Strategies
- Summary, References

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Mobile Broadband Devices and What they Do?





- Dongle (Notepad/netbooks) & Smartphone ~80% of total traffic
- Video(66%), Mobile Web/data (20%), Peer-to-Peer (6%)

Key issue

- Managing OTT video including other Apps efficiently
- Contents caching and delivering close to edge
- Local breakout using Mobile Edge Gateway

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From Cisco VNI Report…

Global mobile data traffic grew 2.6-fold in 2010, nearly tripling for the third year in a row

Last year's mobile data traffic was three times the size of the entire global Internet in 2000. Global mobile data traffic in 2010 (237 petabytes per month) was over three times greater than the total global Internet traffic in 2000 (75 petabytes per month).

Mobile video traffic will exceed 50 percent for the first time in 2011. Mobile video traffic was 49.8 percent of total mobile data traffic at the end of 2010, and will account for 52.8 percent of traffic by the end of 2011.

Mobile network connection speeds doubled in 2010. Globally, the average mobile network downstream speed in 2010 was 215 kilobits per second (kbps), up from 101 kbps in 2009. The average mobile network connection speed for smartphones in 2010 was 1040 kbps, up from 625 kbps in 2009.

The top 1 percent of mobile data subscribers generate over 20 percent of mobile data traffic, down from 30 percent 1 year ago. According to a mobile data usage study conducted by Cisco, mobile data traffic has evened out over the last year and now matches the 1:20 ratio that has been true of fixed networks for several years. Similarly, the top 10 percent of mobile data subscribers now generate approximately 60 percent of mobile data traffic, down from 70 percent at the beginning of the year.

Average smartphone usage doubled in 2010. The average amount of traffic per smartphone in 2010 was 79 MB per month, up from 35 MB per month in 2009.

Smartphones represent only 13 percent of total global handsets in use today, but they represent over 78 percent of total global handset traffic. In 2010, the typical smartphone generated 24 times more mobile data traffic (79 MB per month) than the typical basic-feature cell phone (which generated only 3.3 MB per month of mobile data traffic).

Globally, 31 percent of smartphone traffic was offloaded onto the fixed network through dual-mode or femtocell in 2010. Last year, 14.3 petabytes of smartphone and tablet traffic were offloaded onto the fixed network each month. Without offload, traffic originating from smartphones and tablets would have been 51 petabytes per month rather than 37 petabytes per month in 2010.

Android approaches iPhone levels of data use. At the beginning of the year, iPhone consumption was at least 4 times higher than that of any other smartphone platform. Toward the end of the year, iPhone consumption was only 1.75 times higher than that of the second-highest platform, Android.

In 2010, 3 million tablets were connected to the mobile network, and each tablet generated 5 times more traffic than the average smartphone. In 2010, mobile data traffic per tablet was 405 MB per month, compared to 79 MB per month per smartphone.

There were 94 million laptops on the mobile network in 2010, and each laptop generated 22 times more traffic than the average smartphone. Mobile data traffic per laptop was 1.7 GB per month, up 49 percent from 1.1 GB per month in 2009.

Nonsmartphone usage increased 2.2-fold to 3.3 MB per month in 2010, compared to 1.5 MB per month in 2009. Basic handsets still make up the vast majority of devices on the network (87 percent).

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From Cisco VNI Report…

There are 48 million people in the world who have mobile phones, even though they do not have electricity at home. The mobile network has extended beyond the boundaries of the power grid.

Global mobile data traffic will increase 26-fold between 2010 and 2015. Mobile data traffic will grow at a compound annual growth rate (CAGR) of 92 percent from 2010 to 2015, reaching 6.3 exabytes per month by 2015.

There will be nearly one mobile device *per capita* by 2015. There will be over 7.1 billion mobile-connected devices, including machine-to-machine (M2M) modules, in 2015-approximately equal to the world's population in 2015 (7.2 billion).

Mobile network connection speeds will increase 10-fold by 2015. The average mobile network connection speed (215 kbps in 2010) will grow at a compound annual growth rate of 60 percent, and will exceed 2.2 megabits per second (Mbps) in 2015.

Two-thirds of the world's mobile data traffic will be video by 2015. Mobile video will more than double every year between 2010 and 2015. Mobile video has the highest growth rate of any application category measured within the Cisco VNI forecast at this time.

Mobile-connected tablets will generate as much traffic in 2015 as the entire global mobile network in 2010. The amount of mobile data traffic generated by tablets in 2015 (248 petabytes per month) will be approximately equal to the total amount of global mobile data traffic in 2010 (242 petabytes per month). The same will be true of M2M traffic, which will reach 295 petabytes per month in 2015.

The average smartphone will generate 1.3 GB of traffic per month in 2015, a 16-fold increase over the 2010 average of 79 MB per month. Aggregate smartphone traffic in 2015 will be 47 times greater than it is today, with a CAGR of 116 percent.

By 2015, over 800 million terabytes of mobile data traffic will be offloaded to the fixed network by means of dual-mode devices and femtocells. Without dual-mode and femtocell offload of smartphone and tablet traffic, total mobile data traffic would reach 7.1 exabytes per month in 2015, growing at a CAGR of 95 percent.

The Middle East and Africa will have the strongest mobile data traffic growth of any region at 129 percent CAGR, followed by Latin America at 111 percent and Central and Eastern Europe at 102 percent.

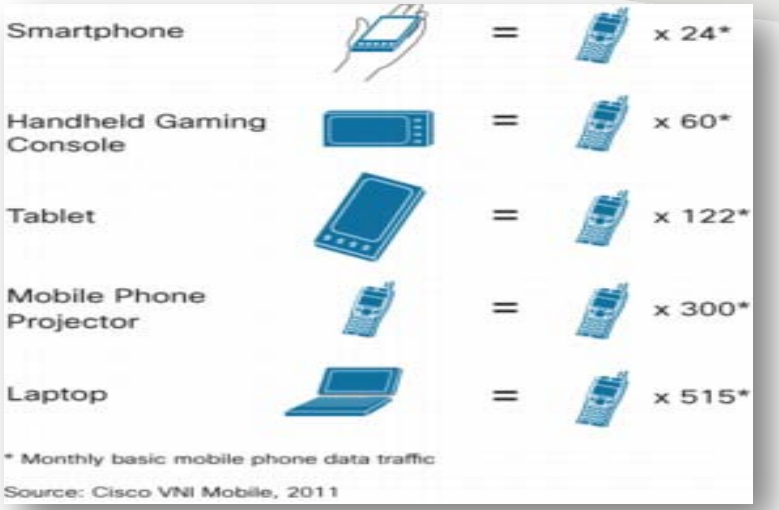
There will be 788 million mobile-only Internet users by 2015. The mobile-only Internet population will grow 56-fold from 14 million at the end of 2010 to 788 million by the end of 2015.

The mobile network will break the electricity barrier in more than 4 major regions by 2015. By 2015, 4 major regions (Sub-Saharan Africa, Southeast Asia, South Asia, and the Middle East) and 40 countries (including India, Indonesia, and Nigeria) will have more people with mobile network access than with access to electricity at home. The off-grid, on-net population will reach 138 million by 2015.

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Device Comparisons

Cisco VNI Report 2010-2015





- Top 10% Devices generate 60% of total traffic
- Android is catching fast iOS with iPhone for usage
- Device operating system & Apps have unique characteristics impacting signaling and bearer traffic

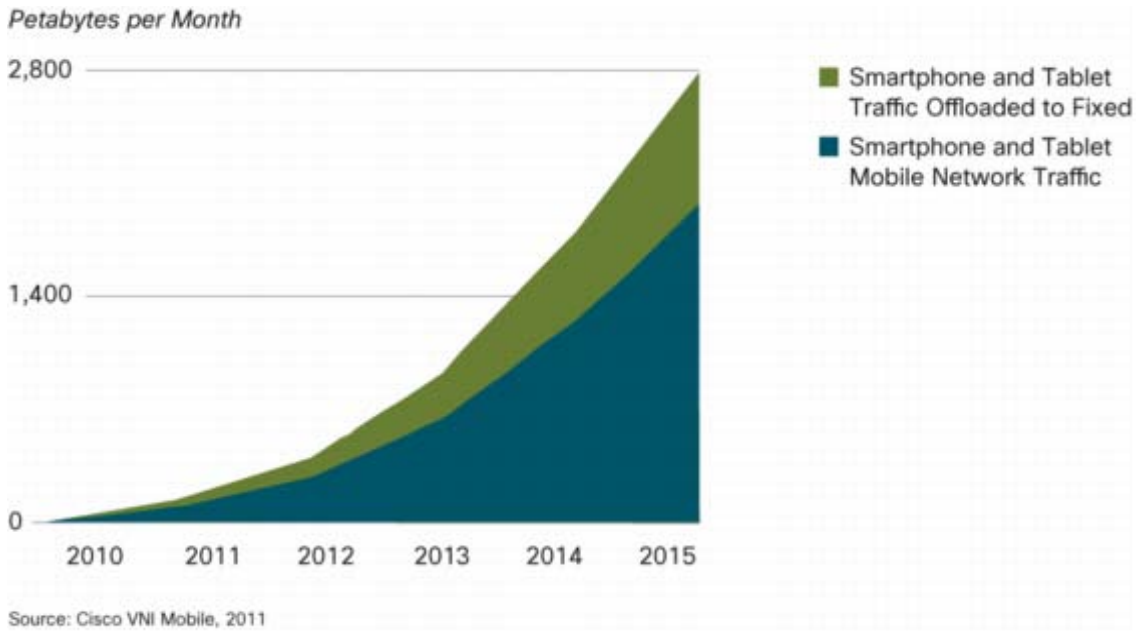
Challenge of Smartphone

- Radio signaling overload, simultaneous device updates
- Bandwidth hogging, Concurrent flows, Keeping NAT pin holes
- Malware (DOS/DDoS) attack

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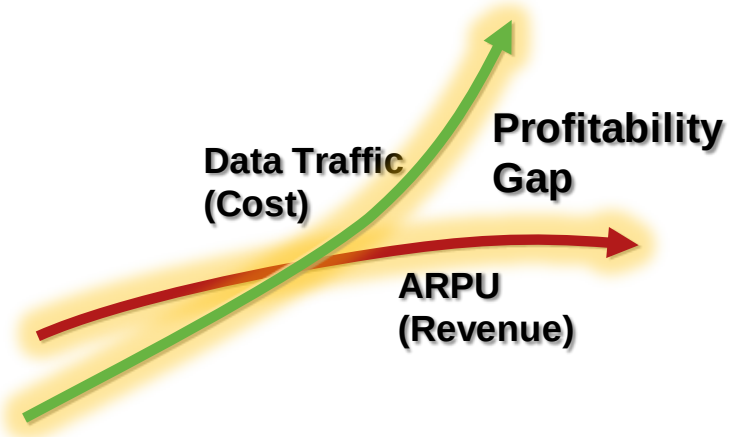
Mobile Data offload

- Mobile data offload free-up macro network
  - Enhance user experience due to more bandwidth
  - Offload is integral part of overall design
  - Offload technologies – SP WiFi, Femto etc…
- Benefit out-weight network complexities due to offload



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Mobile Operator's Challenges and Opportunity



Increase Revenue

In-house Apps

B2B2C Business Model

Enable Content and Partnerships

Reduce Costs

Manage "Over The Top"

Offload internet traffic at edge

Optimal use of expensive assets

Improve Experience

Innovative services

3-screen experience, session shifting quality of video experience

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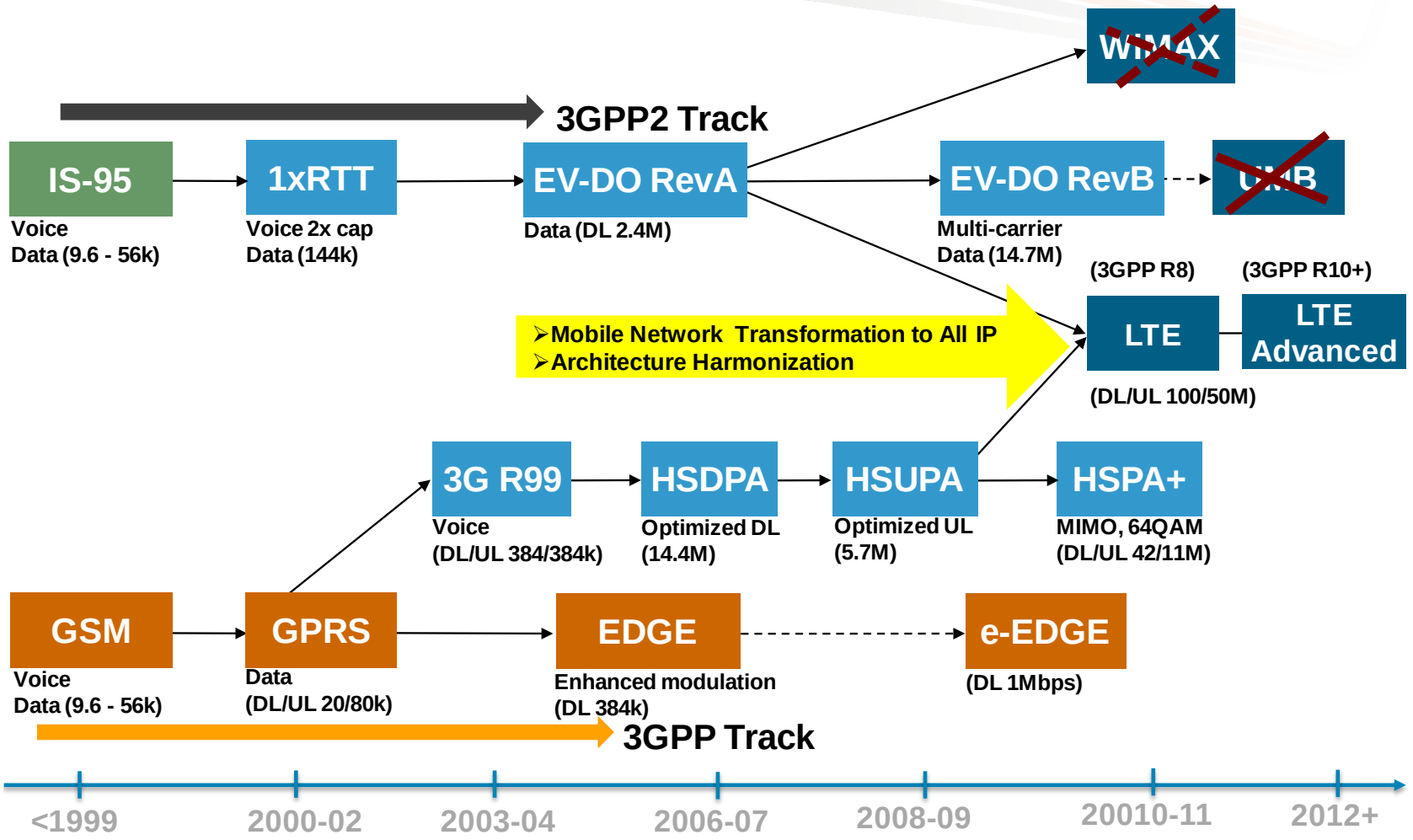
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Mobile Network Evolution – Convergence to LTE*

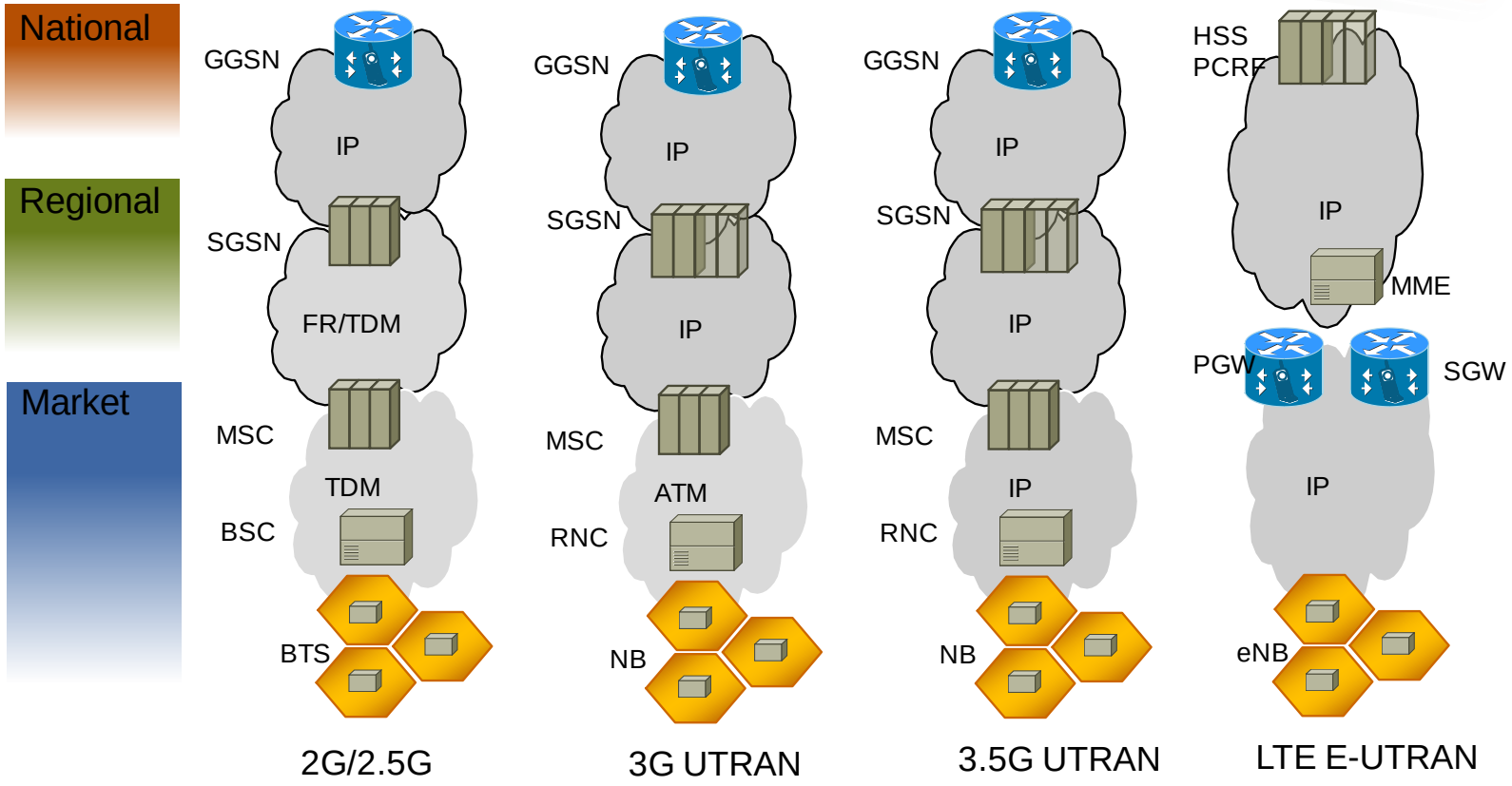


* Actual speed depend upon many factors

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Hierarchical Architecture



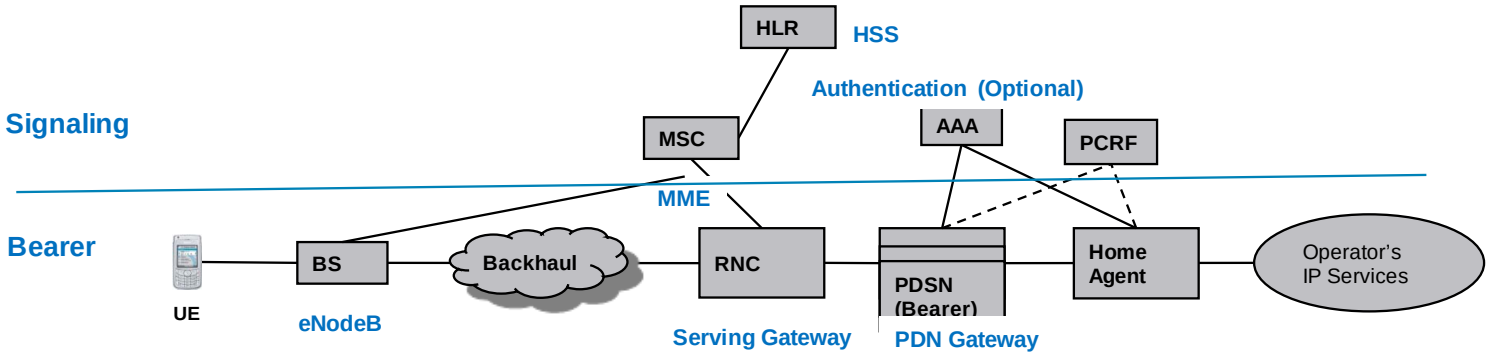
MME – Mobility Management Entity, SGW – Serving Gateway, PGW – PDN Gateway

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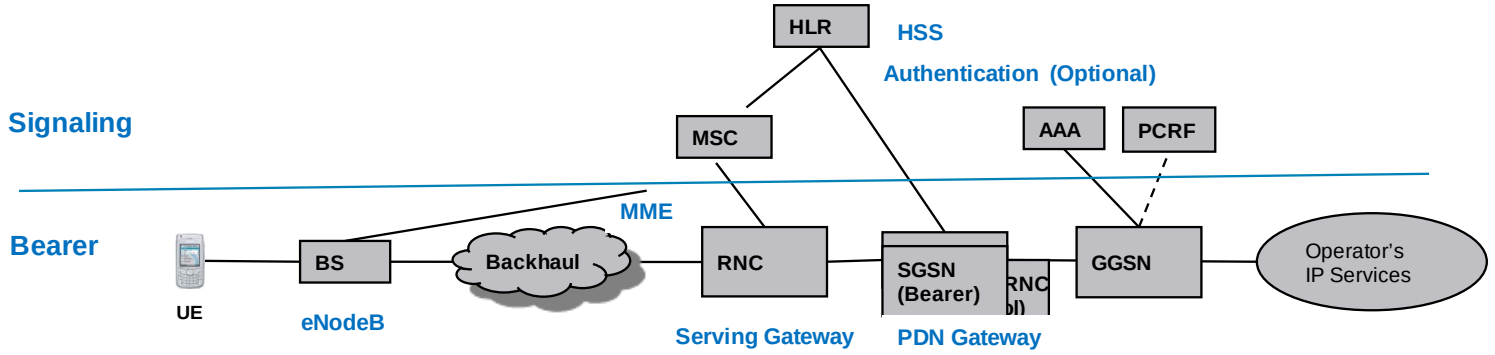
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LTE Functional Migration from 3G

CDMA to LTE Migration



UMTS to LTE Migration



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LTE Functional Migration from 3G

LTE Term	CDMA Equivalent	UMTS Equivalent
eUTRAN (Evolved Universal Terrestrial Radio Access Network)	AN (Access Network)	UTRAN
eNode B (Evolved Node B)	Base station + RNC	Base station + RNC
EPC (Evolved Packet Core)	PDN (Packet Data Network)	PDN
MME (Mobility Management Entity)	RNC + PDSN (Control part)	SGSN (Control Part)
SGW (Serving Gateway)	PDSN + PCF (Bearer part)	SGSN (Bearer Part)
PDN GW (Packet Data Network Gateway)	HA (Home Agent)	GGSN (Gateway GPRS Support Node)
HSS (Home Subscriber System)	AAA + HLR	AAA + HLR
S1-MME (eNode B <-> MME for Control)	A10 / A11 / A12	Iu
S1-U (eNode B <-> SGW for Bearer)	A10 + R-P Session	Gn
S5/S8 Bearer (SGW <-> PDNGW)	MIP (Mobile IP Tunnel)	Gn, Gb
EPS Bearer Service (E2E traffic path between UE and PDN GW)	PPP + MIP	PDP Context

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LTE: New Terminologies*

LTE Term	Meaning
Access Point Name (APN)	Identifies an IP packet data network (PDN) and service type provided by the PDN to that user's session.
PDN Connection	The Association between an UE and PDN (APN) represented by one IPv4 Address and/or one IPv6 Prefix
GPRS Tunneling Protocol (GTP)	Signaling and Tunneling protocol for data (between eNodeB, SGW, and PGW)
EPS Bearer	An EPS bearer uniquely identifies traffic flows that receive a common QoS treatment between UE and PDN-GW
Default Bearer	First one to get established and remains established throughout the lifetime of PDN Connection.
Dedicated Bearer	Additional bearer(other than default), created for a PDN connection to provide specific QoS treatment for Apps
Tracking Area Update (TAU)	Signaling Procedure performed by the UE to move between MMEs
QoS Class Indicator (QCI)	Field indicating type of service associated with a data packet.
Traffic Flow Template (TFT)	A traffic filter that identifies an application class. This is associated with a Dedicated Bearer and QCI.

*Some of the terms are known to UMTS operators, but new to CDMA Operators

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LTE: New Terminologies*

LTE Term	Meaning
Guaranteed Bit rate (GBR) Bearer	Dedicated network resources Allocated permanently at bearer establishment/modification
Non-Guaranteed Bit rate (non- GBR) Bearer	No dedicated network resource are reserved Default bearer is always non- GBR Bearer
APN-AMBR	Aggregated maximum bit rate associated with all the non- GBR bearers across all PDN connections connected to given APN. Stored in HSS/HLR per APN Not applicable to GBR bearers
UE-AMBR	Aggregated maximum bit rate for UE Subscription parameter and stored in HSS/HLR per UE
QoS	Access agnostic QoS definition QoS Class Identifier (QCI) Allocation and Retention Priority Guaranteed and Maximum Bit Rates

*Some of the terms are known to UMTS operators, but new to CDMA Operators

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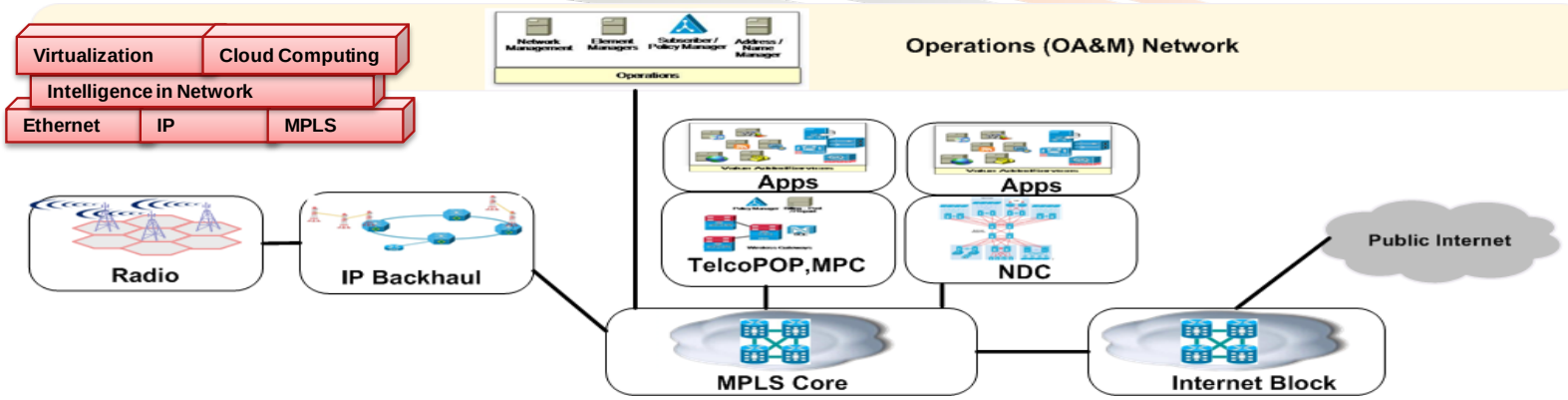
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LTE Architecture Framework

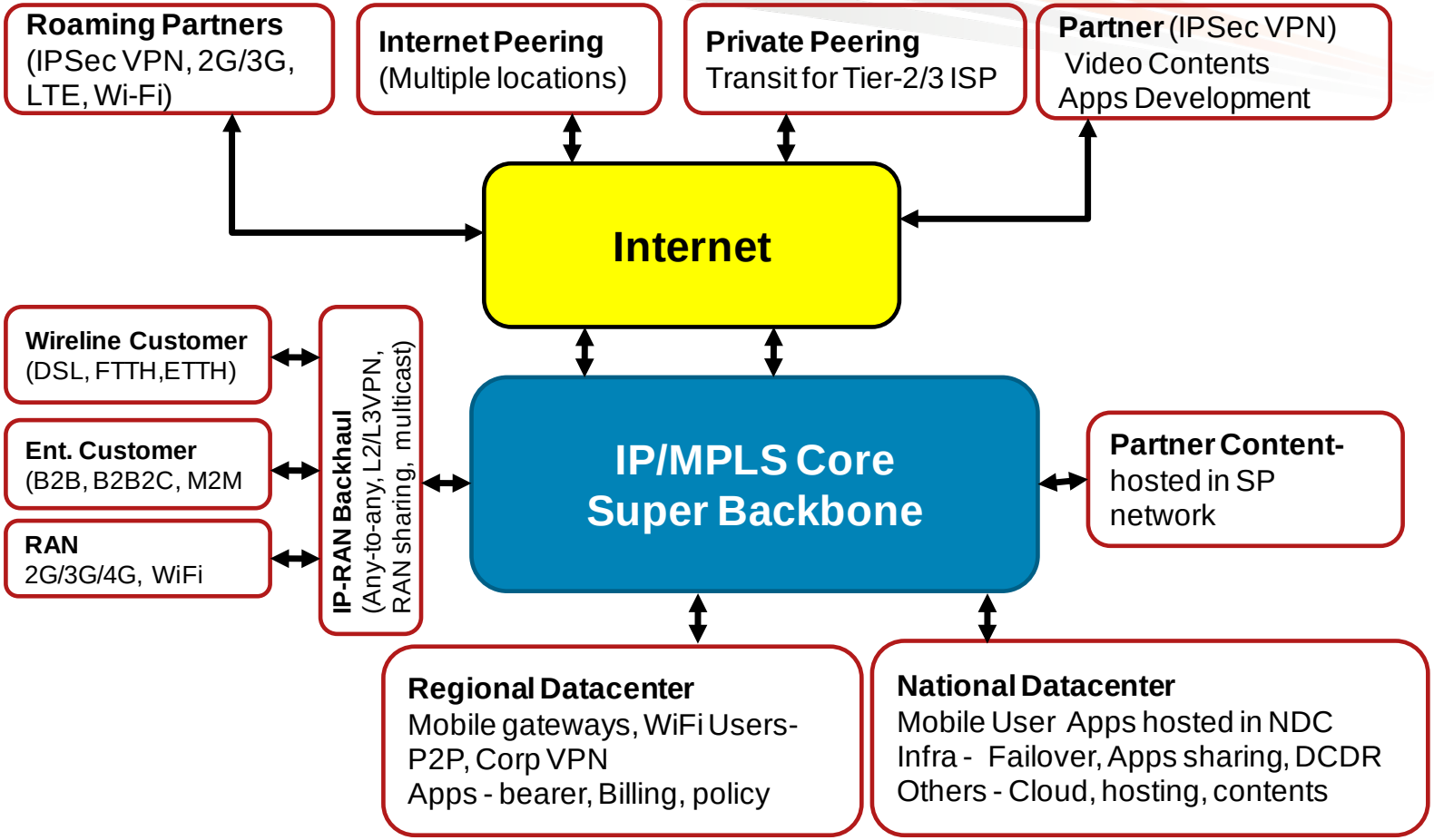


IP-RAN	MPLS Core	Packet Core	National Datacenter
▪ **1 GE to Cellsite** - Cellsite (1GE) - Access (10GE) - Aggregation (40GE) ▪ Ethernet – lease/build ▪ uWave, Fiber media ▪ Support 2G/3G/4G ▪ IP/MPLS (L2/L3VPN) ▪ Multicast capable ▪ Traffic Offload ▪ H-QoS ▪ IPv6	▪ **100GE enabled** ▪ BGP free, MPLS enabled core ▪ Scalable Routing ▪ L3VPN as needed ▪ Limited L2VPN ▪ Traffic Engineering ▪ Multi-exit Internet ▪ 6PE, 6VPE	▪ **10-100 GE enabled** ▪ POD architecture ▪ Distributed Gateways ▪ User policy & QoS ▪ Bearer traffic ▪ Traffic offload and optimize ▪ "SP security" ▪ Optimize OTT ▪ IPv6 on end-points ▪ NAT44/64	▪ **100GE enabled** ▪ Zones & POD ▪ Control traffic ▪ Virtualization ▪ Storage ▪ Cloud computing will drive next-gen M2M communication ▪ IMS Apps ▪ IPv6

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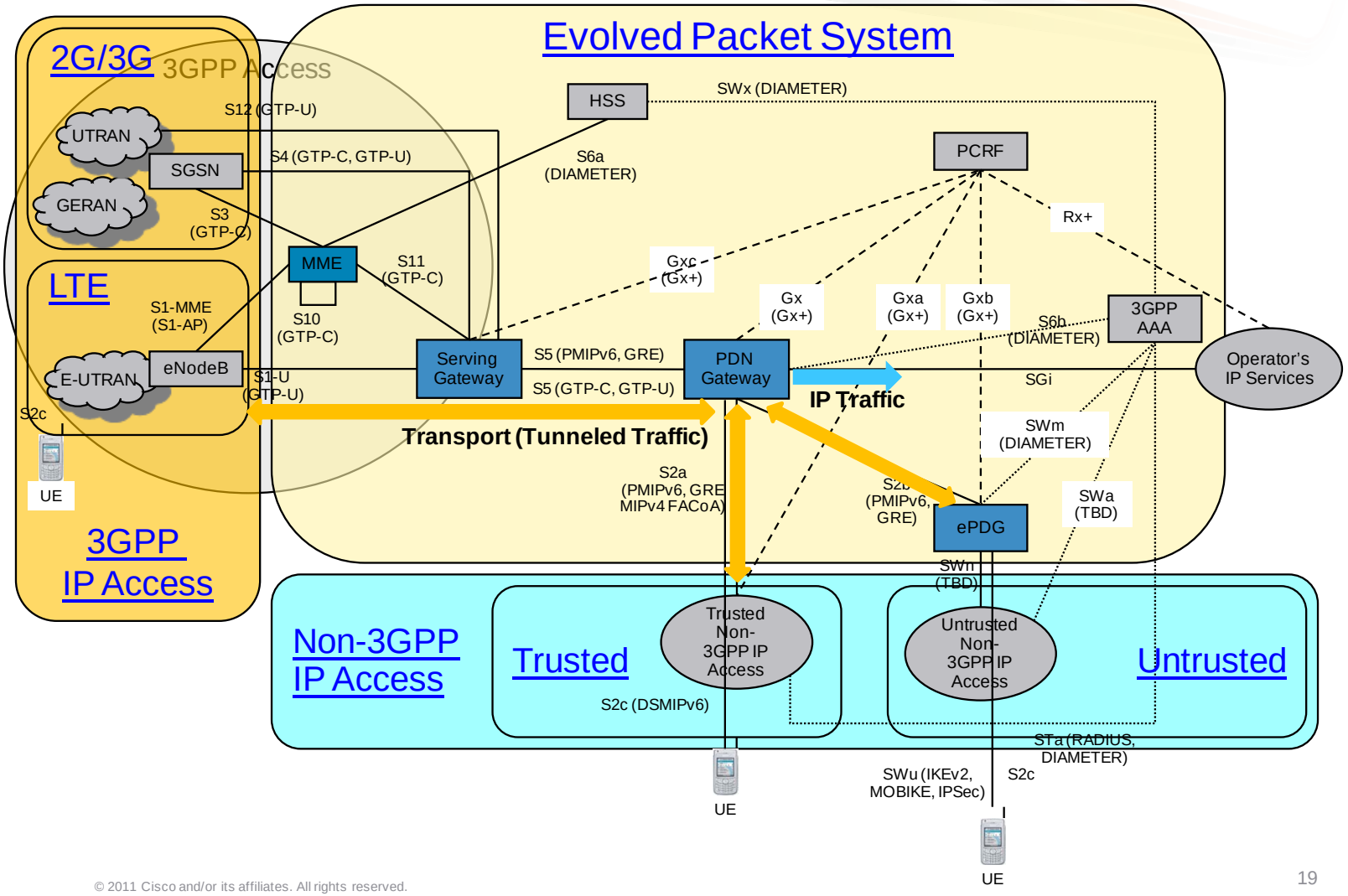
Network Core Architecture



Simple, scalable, resilient architecture using optimal resources and support multiple services on the same backbone infrastructure

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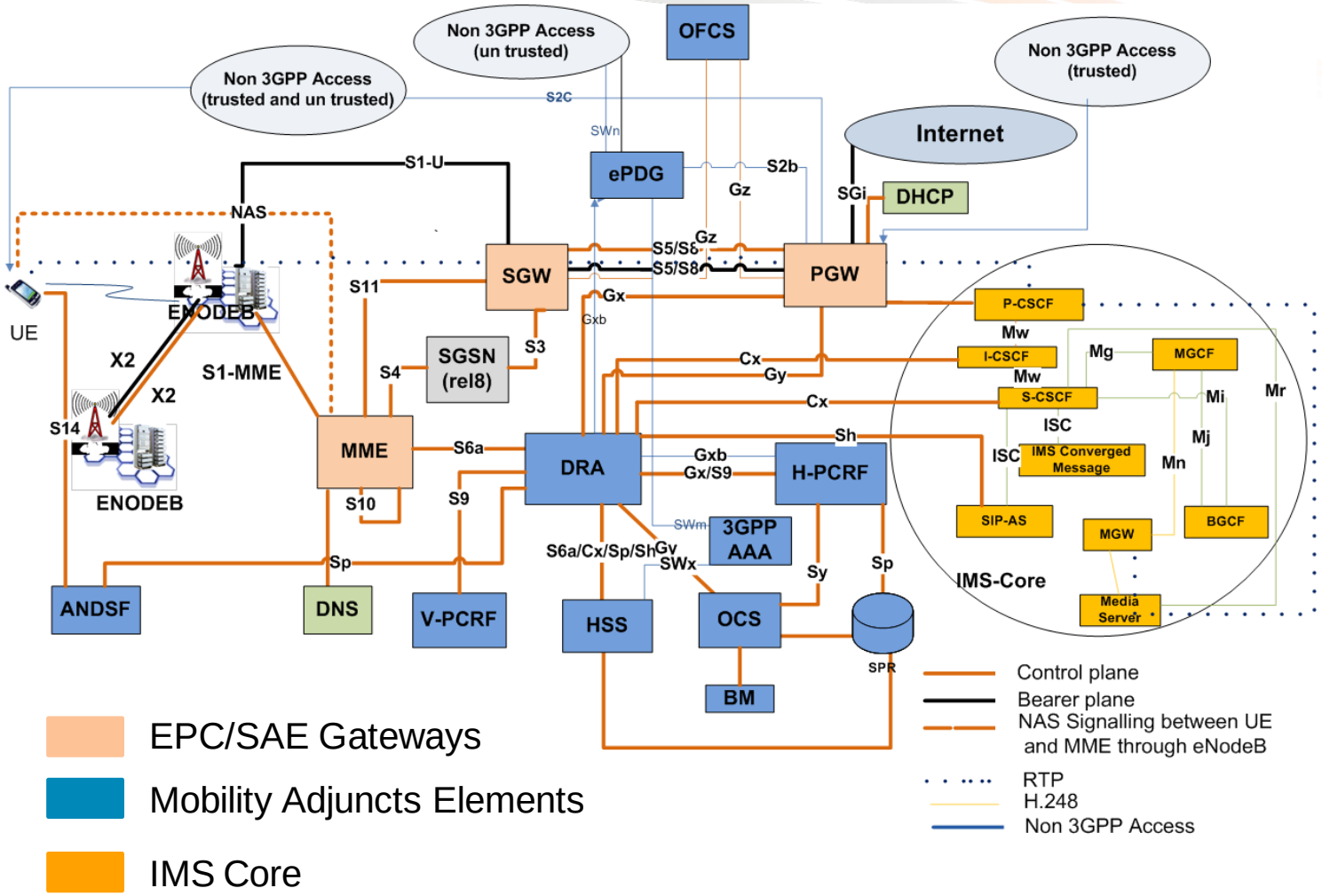
LTE/EPS Reference Architecture – 10,000 Ft View
(Ref 3GPP TS23.401, TS23.402)



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Typical LTE/EPS Architecture – 1,000 Ft View



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Key LTE Requirements

Throughput	• Ideal DL 100Mb/s(5 bps/Hz), 3-4 times Rel 6 HSDPA • Ideal UL 50 Mb/s (2.5 bps/Hz , 2-3 times Rel 6 HSUPA • Different MIMO configuration support
Strict QoS	• Radio Access Network latency < 10 ms, • Control-Plane latency < 100 ms (R8), <50 ms (R9) • User- Plane latency <50 ms for real time Apps & voice
Mobility	• Mobility up to 350 km/h • Roaming with 2/3G networks • WiFi offload capability
Enhanced Multimedia Broadcast Multicast Service (eMBMS)	• Ability to delivery broadcast and multicast to mobiles • Enhanced bit rate for MBMS • Application registration directly by UE to Apps Server
All-IP Architecture	• Any-to-any connectivity – L3VPN, L2VPN, TE • Standard based interfaces • SP security framework

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Agenda

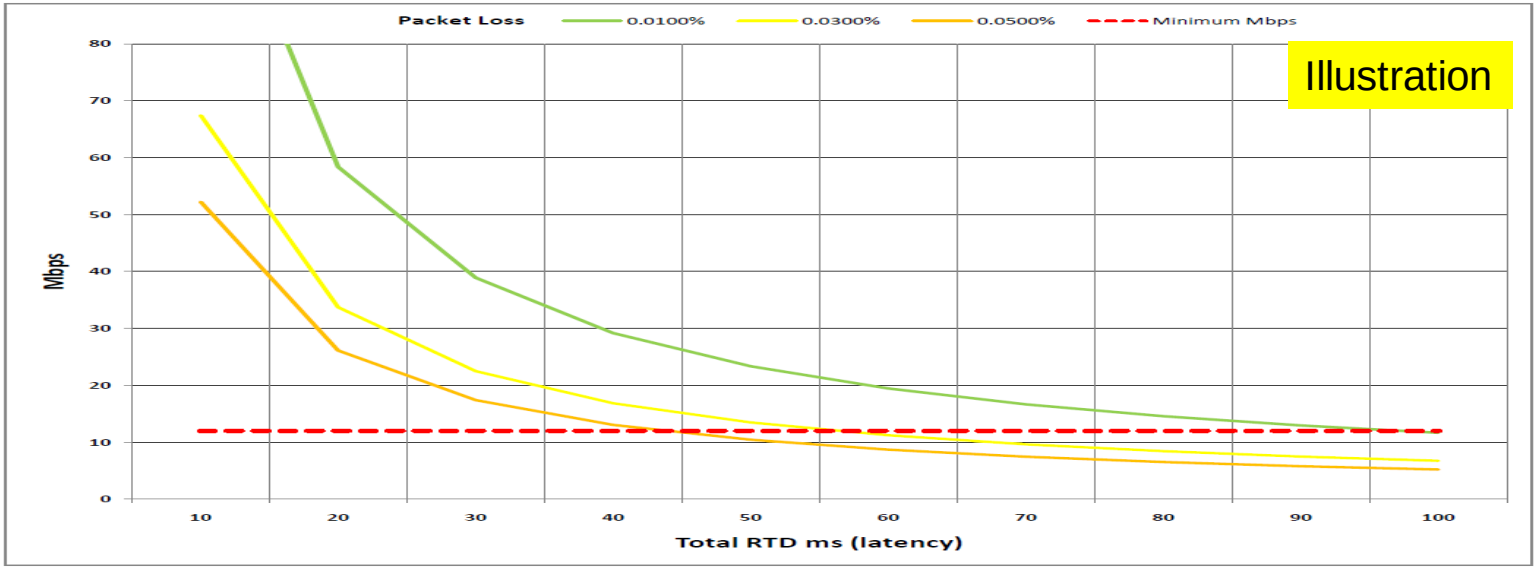
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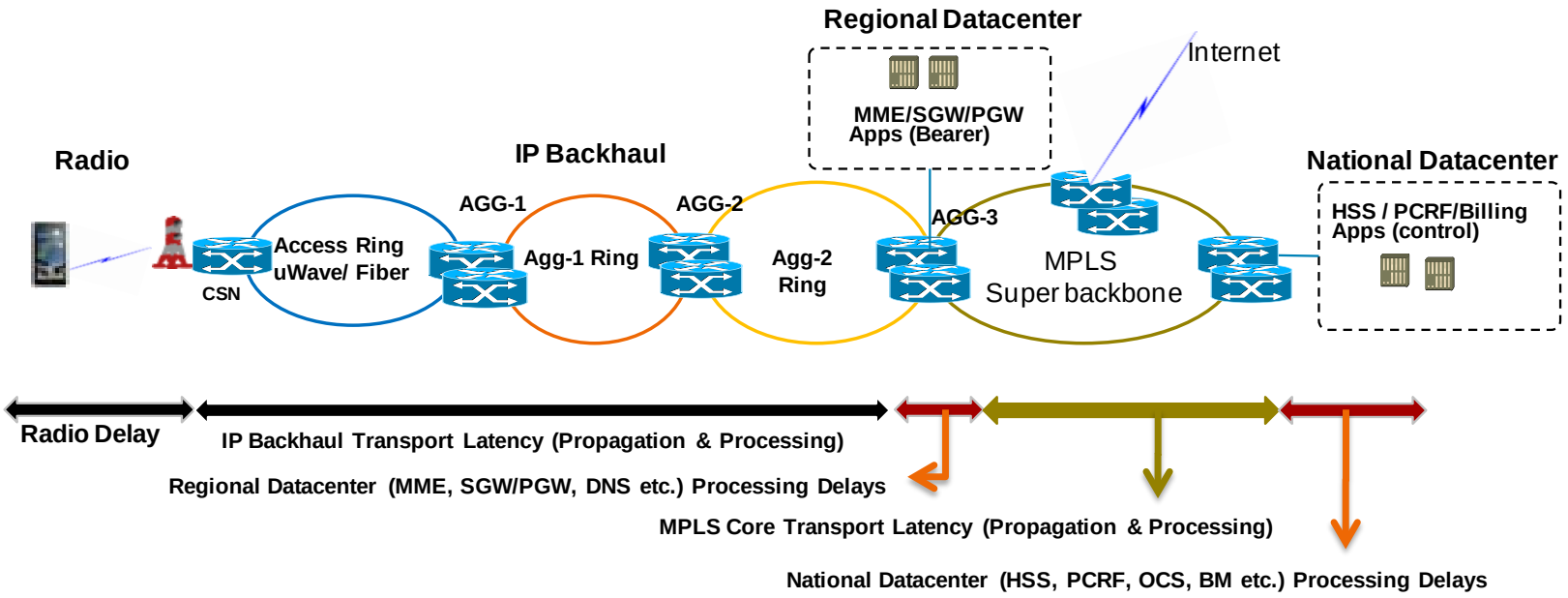
How Does Latency, Packet Loss Impact LTE?

- Latency and delay components
  - Processing delay – depend on CPU, memory and load
  - Serialization delay- depend on packet size and interface speed
  - Queuing delay – depend upon packets in queue & serialization
  - Propagation delay – Depend on distance and media
- Throughput is inversely proportional to roundtrip delay



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Mobile Network and Latency Components

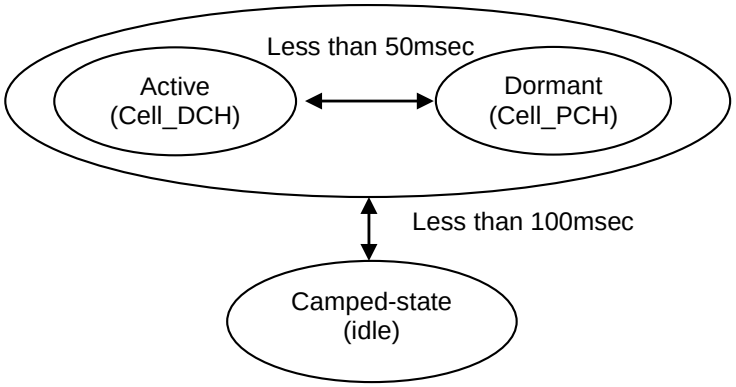


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Latency Requirements

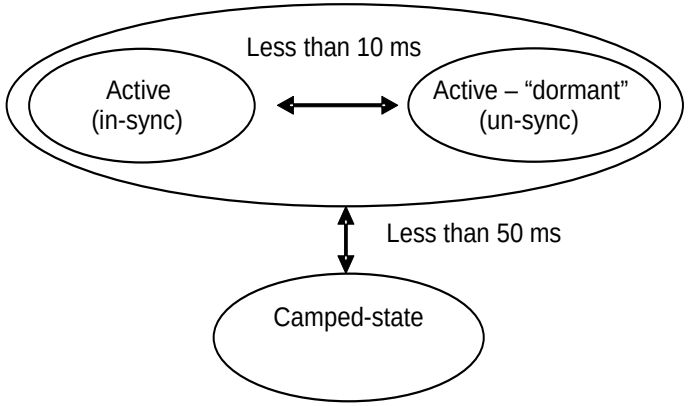
- Control Plane (C-Plane) – Relates to completion of RAN and CN signaling
- User Plan (U-Plane) – Relates to establishment of bearer path

C-Plane Latency (ref TR25.913, V8.0.0)



- Idle to active < 100 ms when user plan is established (excluding paging & NAS)
- Dormant to Active <50 ms

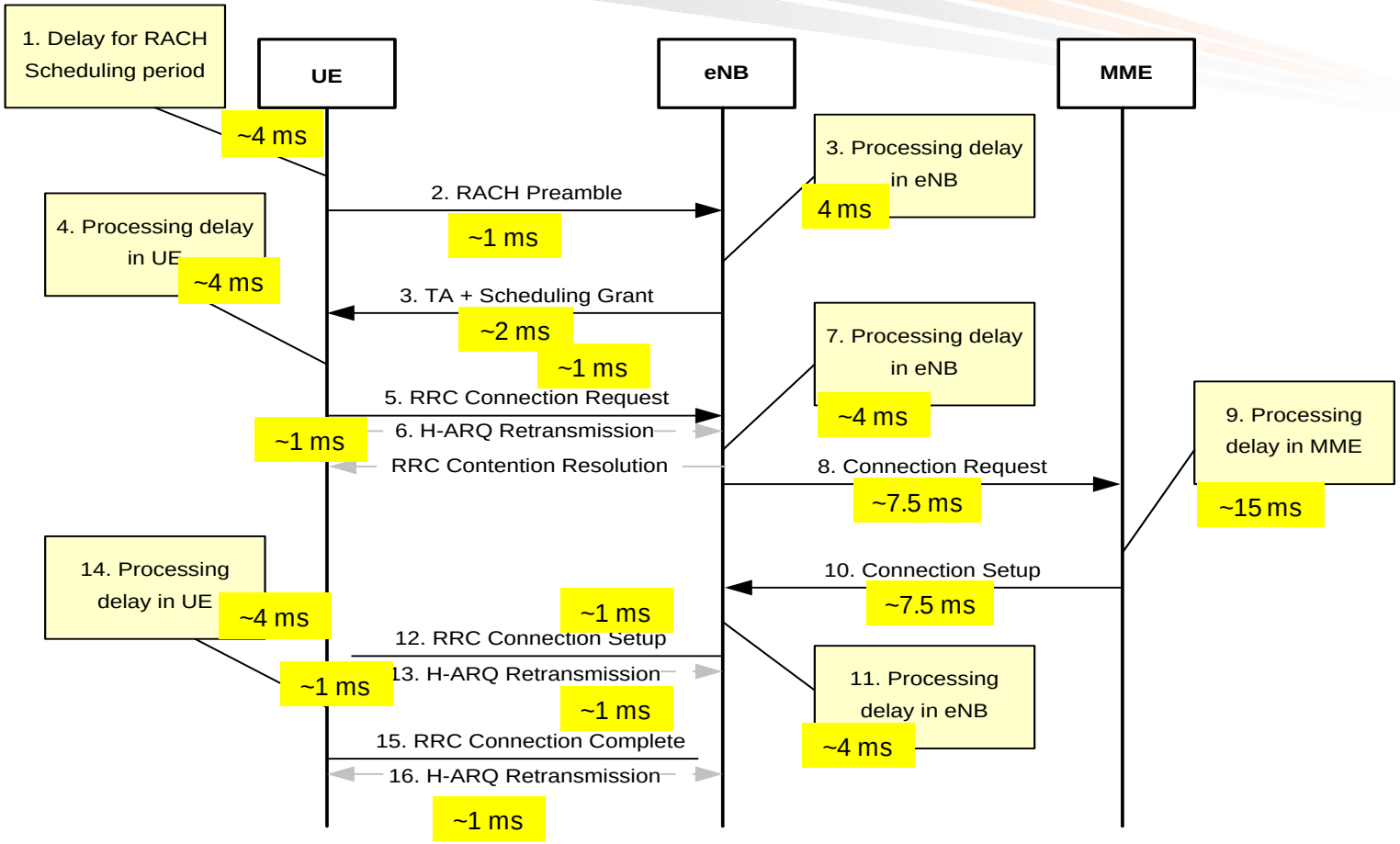
C-Plane Latency (ref TR36.913, V9.0.0)



- Idle to active <50 ms when user plan is established (excludes paging, NAS, S1 transfer)
- Dormant to Active <10 ms

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C-Plane Latency (Idle to Active) -3GPP TS25.912

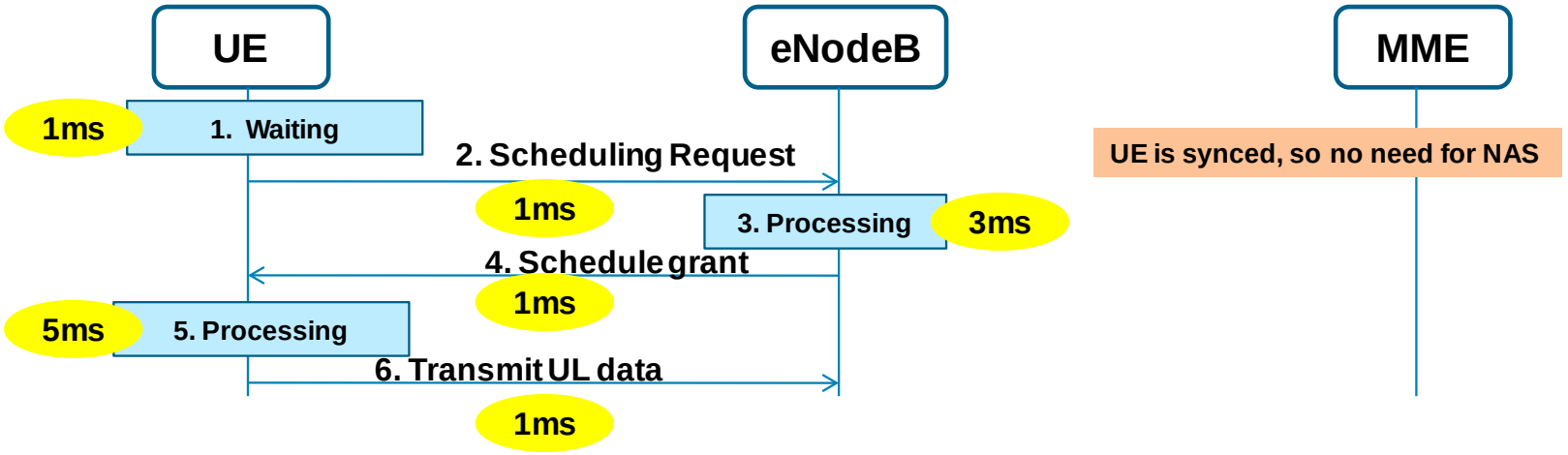


- Total C-Plane = 47.5 ms + 2* S1-C transfer delay ~ 60 ms
- Major components – Processing delays in UE, eNodeB, MME and Transport

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C-Plane Latency (Dormant to Active)- (3GPP TS25.912)



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U-Plane Latency- (3GPP TS25.912)

U-Plane Latency Refers to Establishment of Bearer Path to SGW

Description	Duration
LTE_IDLE→LTE_ACTIVE delay (C-plane establishment)	47.5ms + 2 * Ts1c
TTI for UL DATA PACKET	1ms
HARQ Retransmission (@ 30%)	0.3 * 5ms
eNB Processing Delay (Uu –> S1-U)	1ms
U-plane establishment delay (RAN edge node)	51ms + 2 * Ts1c
S1-U Transfer delay	Ts1u (1ms – 15ms)
UPE Processing delay (including context retrieval)	10ms
U-plane establishment delay (Serving GW)	61ms + 2 * Ts1c + Ts1u

Ts1c = 2ms – 15 ms
Ts1u = 1ms – 15 ms

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Delay Budget for Applications-3GPP TR23.401 V8.1.0

QCI Value	Resource Type	Priority	Delay Budget (1)	Error Loss Rate (2)	Example Services
1 (3)	GBR	2	100 ms	10^{-2}	Conversational Voice
2 (3)		4	150 ms	10^{-3}	Conversational Video (Live Streaming)
3 (3)		3	50 ms	10^{-3}	Real Time Gaming
4 (3)		5	300 ms	10^{-6}	Non-Conversational Video (Buffered Streaming)
5 (3)	Non-GBR	1	100 ms	10^{-6}	IMS Signalling
6 (4)		6	300 ms	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7 (3)		7	100 ms	10^{-3}	Voice, Video (Live Streaming), Interactive Gaming
8 (5)		8	300 ms	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p sharing, progressive download, etc.)
9 (6)		9			

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Delay Budget for Default Bearer Establishment

- Default bearer involve interaction of different entities
- HSS, PCRF, APN-DNS are Apps and will have higher processing delays
- Longer delay for default bearer will be perceived by user

Delay budget measured in production environments

Nodes	Interface name	Nodes Involved	Delay budget (Propagation, processing (ms)
eNB	S1-MME/NAS	eNodeB-MME	~50
MME	S6a	MME-HSS	~100
MME	DNS	MME-DNS (APN)	~50
MME	S11	MME-SGW	~50
SGW	S5/S8	SGW-PGW	~50
PGW	Gx	PGW-PCRF	~100
PGW	Gy	PGW-OCS	~100
		Total bearer set-up time	**~500**
eNodeB	X2	eNB - eNB	20

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Real Time Gaming Requirements

- **First Person Shooter (FPS)**
  - Need fast user response, interactive game
  - Latency – 100 ms (E2E), jitter – 10 ms, Packet loss – 5%
- **Real Time Strategy (RTS)**
  - Slightly relaxed with handful of players, slow response
  - Latency ~250 ms (E2E), jitter-50 ms, Packet loss – 1%
- **Massive Multiplayer Online Role Playing Games (MMORPG)**
  - Many players online, highly variable scenarios.
  - Delay budget – 300 ms (E2E), Packet loss – 5%
- **Non-Real Time Games (NRTG)**
  - No strict criteria for latency e.g. chess
  - Delay budget – 350 ms (E2E), Packet loss – 5%

Summary – Place interactive gaming Apps close to edge

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Agenda

- Mobile Broadband Dynamics
- Mobile Network Evolution
- LTE Architecture Framework
- **LTE Design Strategies**
  - Latency & Delay
  - **IP Planning**
  - MME, SGW, PGW, DNS
  - Transport Planning – Backhaul, MPLS Core
  - Security Framework
- LTE Deployment Strategies
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IPv6 Planning Design Considerations

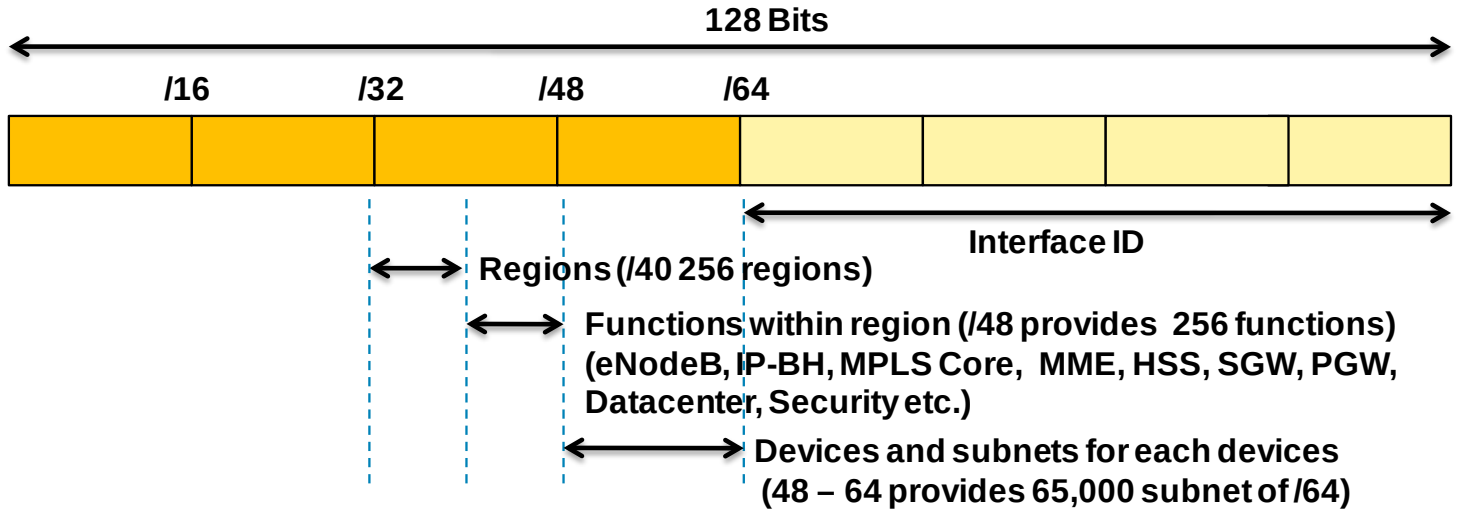
- **Greenfield LTE deployments should be IPv6**
  - Introduce dual stack LTE UE
  - Transport – Dual stack (Preference) or 6PE, 6VPE
  - All LTE Gateway interfaces should be IPv6
  - Internal Apps (i.e. IMS, Video etc.) should be IPv6
  - NAT64 for IPv4 internet
- **Deploying LTE in existing network**
  - Introduce dual stack LTE UE
  - IPv6 for MME(S1-MME, S11), SGW(S1-U, S5/S8), PGW(S5/S8, SGi)
  - Transport – 6PE, 6VPE to support LTE
  - Convert Internal Apps (i.e. IMS, Video etc.) to IPv6
  - Create Services islands- served by IPv4, IPv6
  - NAT64 for IPv4 internet
  - Integrate with existing 2.5/3G network on IPv4

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IPv6 Subnet Considerations for Infrastructure

- Infrastructure subnets are typically not announced to internet
- Summarization – optimize routing and easy to scale
- Point-to-point Interface address: Choices - /127, /64
- Loopback /128

Subnetting Example (Assuming - /32 for Infrastructure)



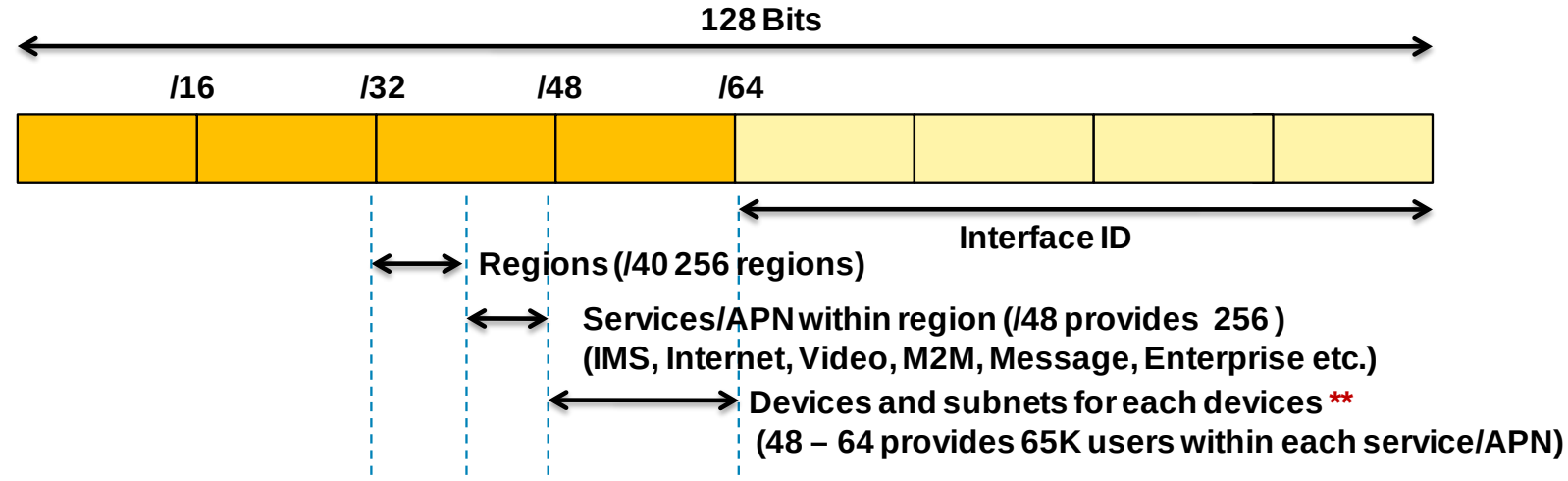
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IPv6 Subnet Considerations for Subscribers

- LTE Users IPv6 subnets are announced to internet
- Separate block for each service i.e. APN/virtual APN
- Allocation strategy – Local Pool, AAA, DHCPv6
- Subnet strategy – Ability to identify services, easy growth

Subnetting Example (Assuming /32 for LTE Users)

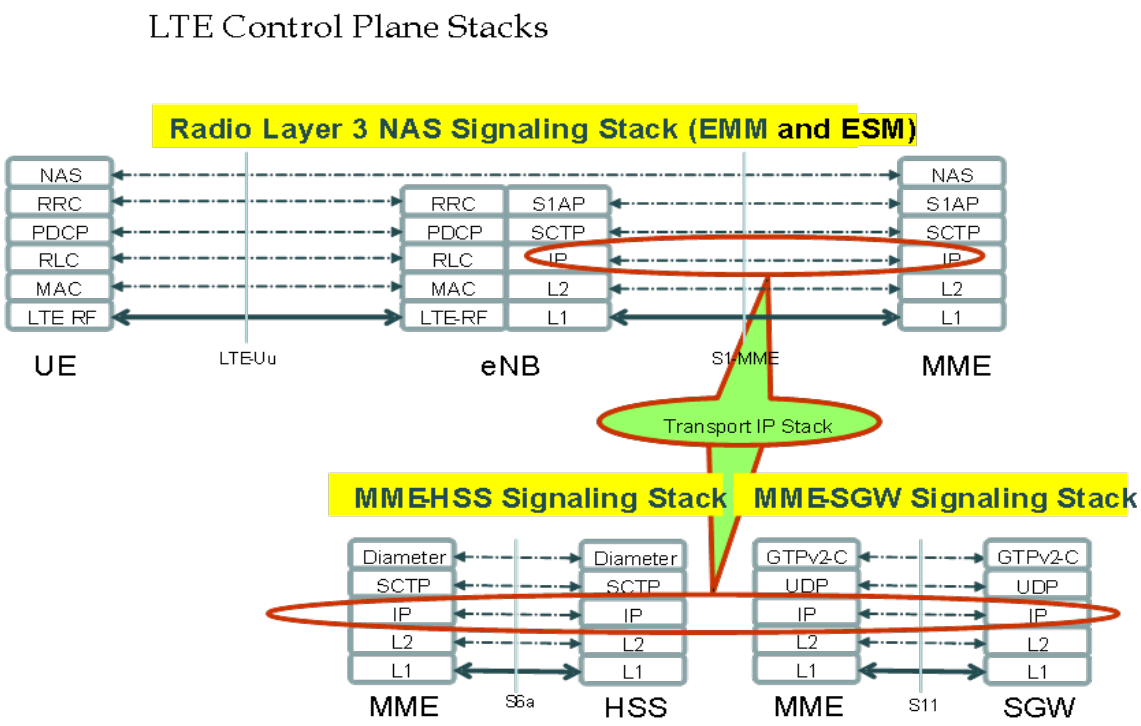


** For wireless routers gateway allocated smaller block i.e. /60, /56 or /48 etc.

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Transport Traffic – Control

- Provide user authentication, establish data sessions
- Network Layer - IPv4, Dual stack or native IPv6
- Transport - Radio Access Network & Mobile Backhaul

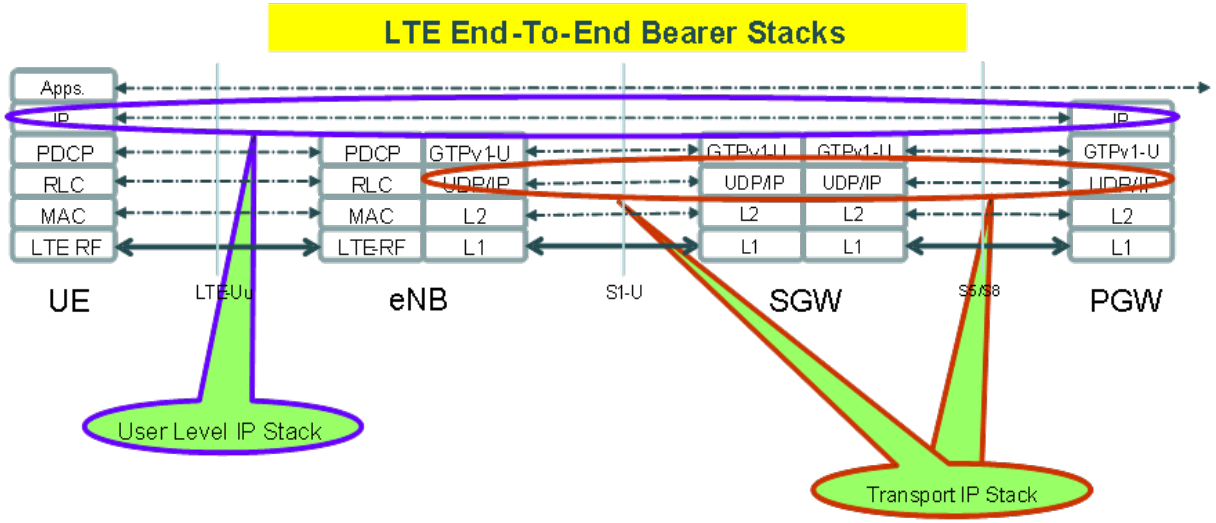


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Transport Traffic - Bearer

- Two way user traffic between **Users** and **Applications**
- Encapsulated in tunnel (GTP)
- Default Bearer and Dedicated Bearer(s) if Required
- Service Level QoS

LTE Bearer Plane Stacks

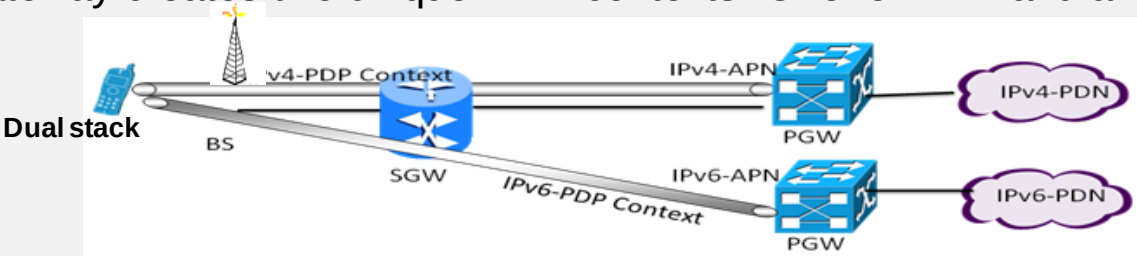


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Transport Traffic - Bearer Setup for Subscriber

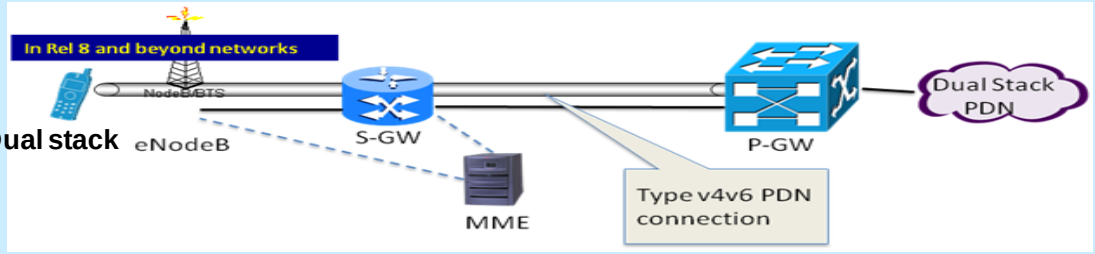
Prior to 3GPP Rel-8 (LTE introduced from Rel-8 onward)

- Dual-stack User sends two PDP requests- One of for IPv4 and another for IPv6
- Gateway creates two unique PDP-contexts- One for IPv4 and another for IPv6.



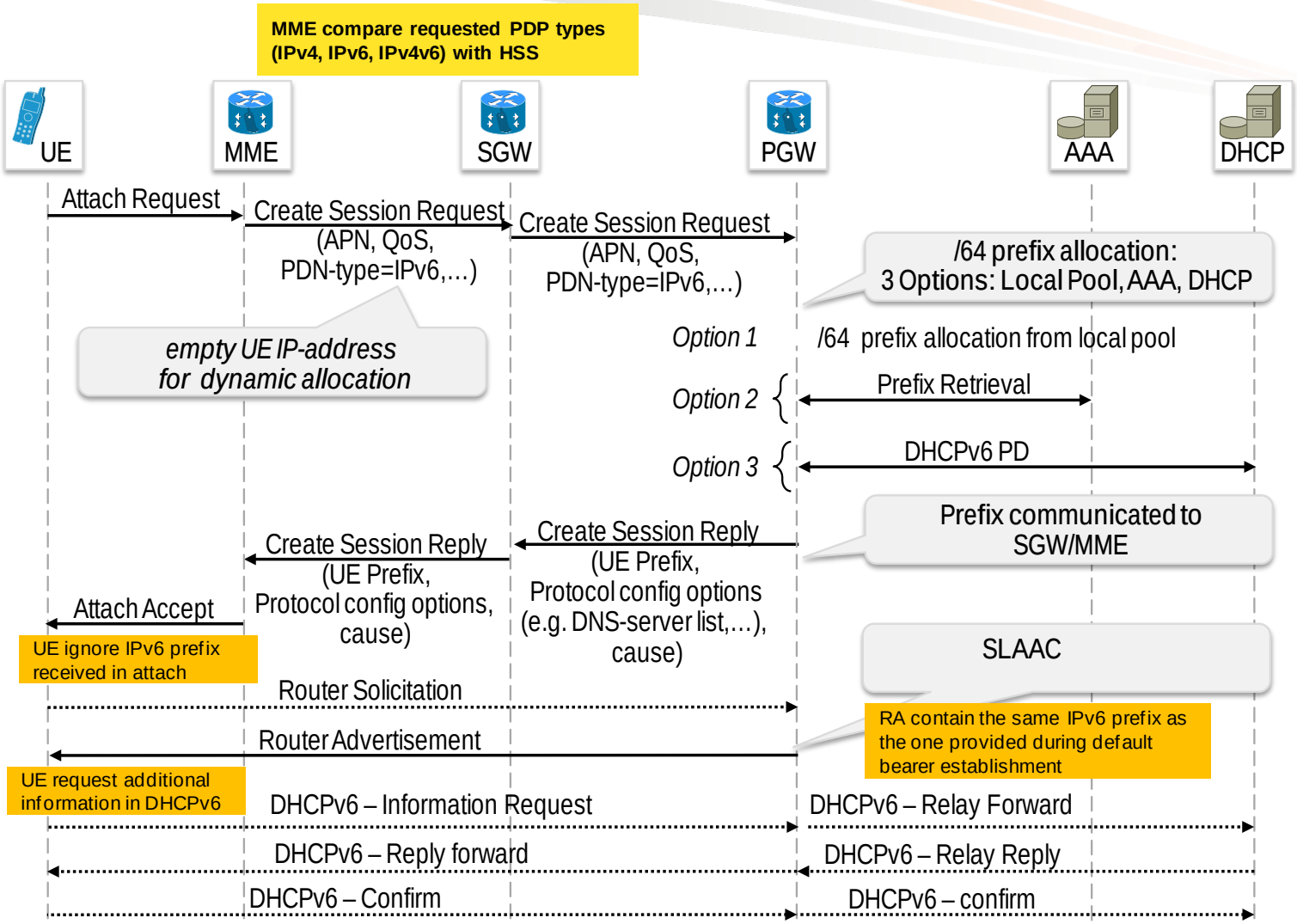
3GPP Rel-8 onward

- Dual stack User send one PDP request “IPv4v6”
- Gateway will create bearer; Allocate IPv4 & IPv6 to same bearer
- For GPRS network single bearer is applicable from 3GPP Rel-9 onward



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Subscriber IPv6 Address Allocation

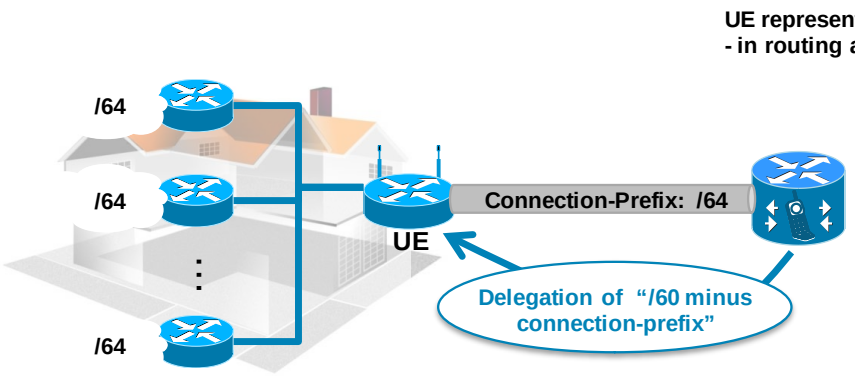


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Mobile Router (3GPP Rel-10)

FUTURE



- Enable LTE UE to work as Mobile router (/60) & Each client get /64
- Prefix Delegation w/ DHCPv6 PD (RFC3633) on top of existing address
- LTE UE request DHCPv6 Prefix delegation
- DHCPv6 allocate prefix (e.g. /60) "prefix minus connection-prefix" delegated using Prefix-Exclude option (see draft-korhonen-dhc-pd-exclude)
- LTE UE further allocate /64 to clients minus connection-prefix

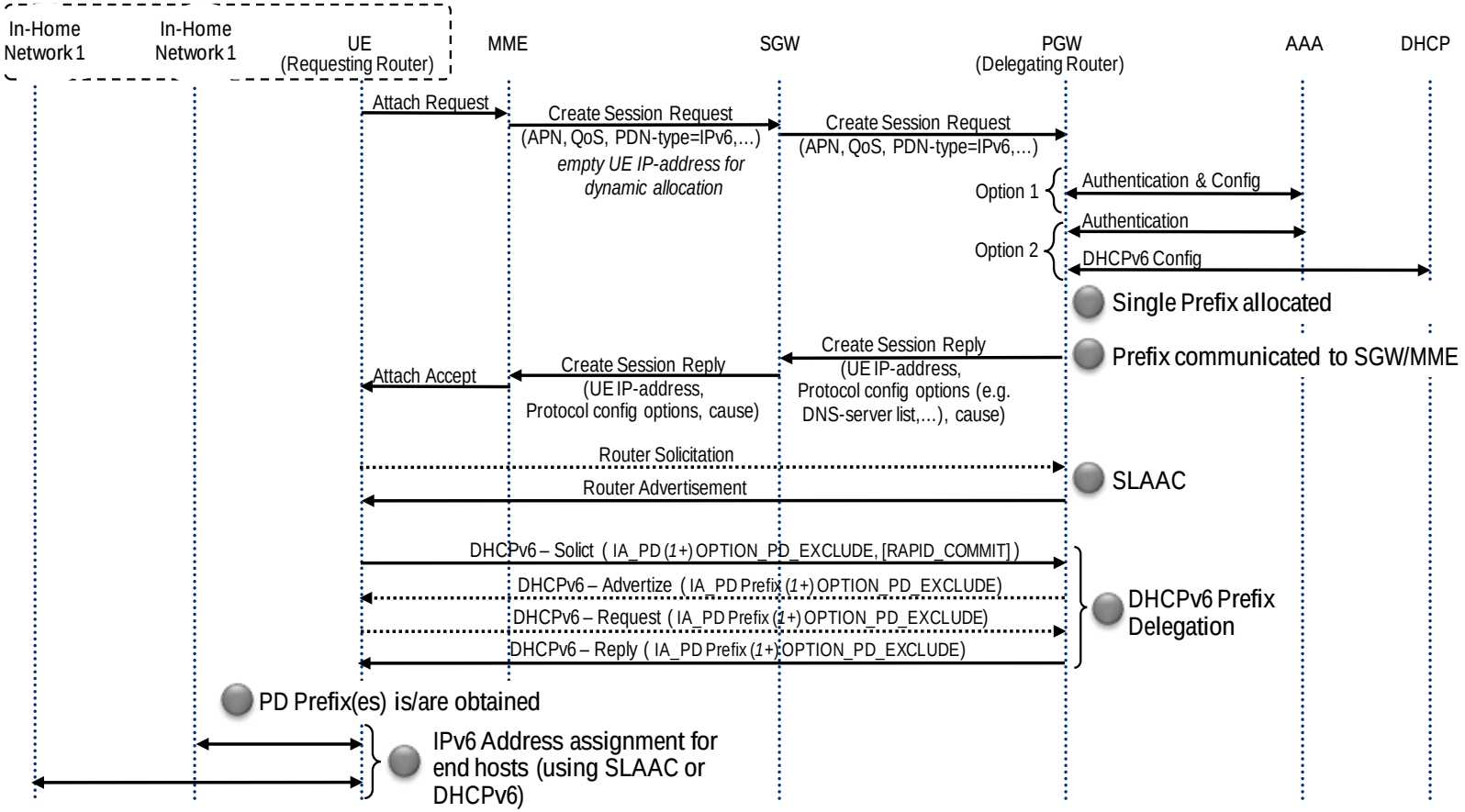
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IPv6 Prefix Delegation in 3GPP Network

3GPP TS 23.060 & 23.401 (Rel-10)

FUTURE



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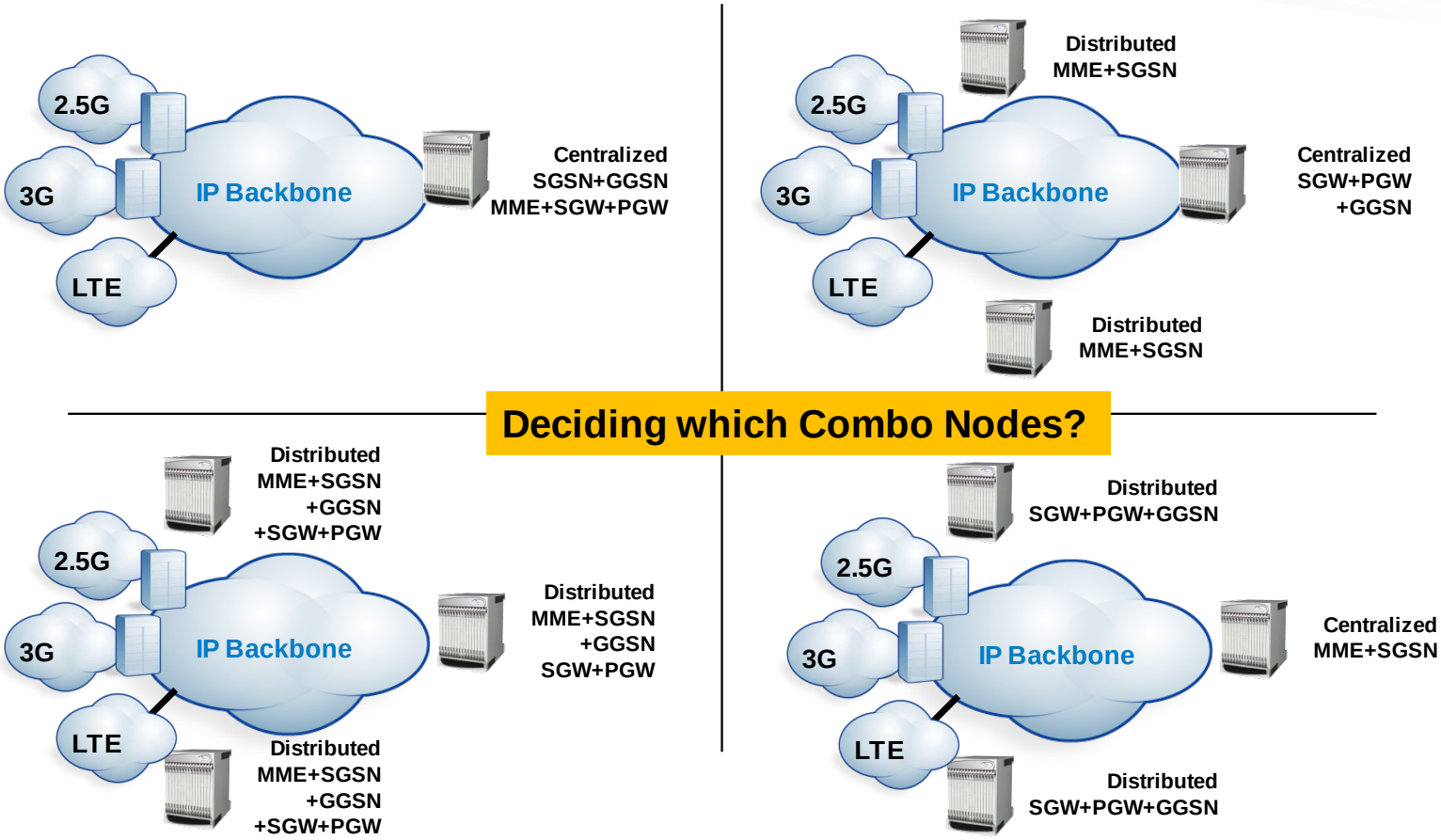
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Design Considerations



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Recommendation LTE/EPC Gateways Location

Entity	Placement Considerations
MME	**Moderate distribution** • Latency <50ms from eNB to MME (S1-MME), • Faster signaling/call setup • Use MME pooling - scaling & geographical redundancy
SGW/PGW	**Distributed, close to edge** •Ability to serve video locally •Latency <50 ms from eNB (S1-U), better user experience •Co-locate/Co-host SGW/PGW if design permit •Mobile Service Edge gateway (MSEG) might be an option to offload user traffic, closer to edge
HSS	**Centralized/Moderate distribution** • Latency <100 ms. Latency impact default bearer set-up • Partition HSS as front end and backend if design permit • Front-end co-locate with MME if possible
SPR/DBE	**Centralized** • Latency <100 ms. Latency impact database query, sync • Replicate database at multiple locations • Co-locate with HSS backend

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Recommendation LTE/EPC Gateways Location

Entity	Placement Considerations
PCRF, Balance Manager, Online Charging System	**Centralized** • Latency <100 ms. Latency impact policy download, updates • Can share database with HSS • Balance Manager, Online Charging co-located with PCRF
DNS	•Tracking Area/APN DNS – Used by MME, Centralized •Mobile DNS – Used by UE, distributed. Co-located with PGW •Internet DNS – Used for inbound query, Centralized •Roam DNS – Used by roaming partners, Centralized •Infrastructure DNS – Used by internal infrastructures, Centralized
AAA	**Centralized** •Used for ePDG (3GPP) – centralized •Infra. device authentication - centralized
DHCP	**Centralized** •DHCPv6 for IP address allocation

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MME Design Parameters

MME Handle Control Plane Signaling Toward eNB, HSS, SGSN, SGW etc.

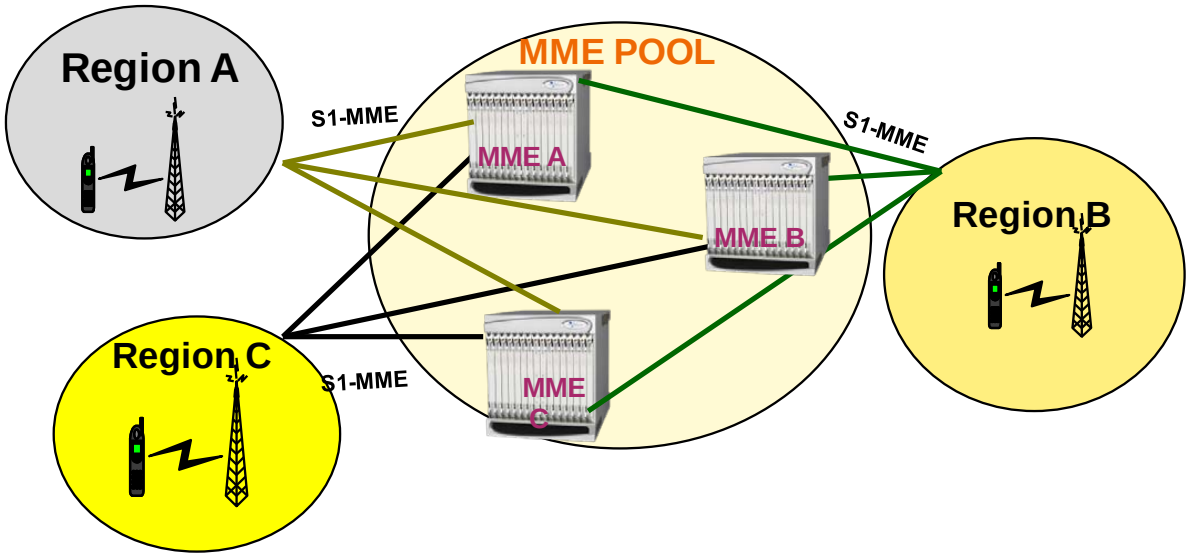
	MME parameters Per sub/Hr	Typical values**
1	Initial UE Attach/Detach	
2	Bearer activation/deactivation per PDN session	
3	PDN connection setup/tear down	
4	Ingress paging	
5	Egress paging	
6	Idle-active/active-idle transactions	
7	Number of bearer per PDN session	
8	Number of PDN sessions	
9	Intra-MME S1 handover **with** SGW relocation	
10	Intra-MME S1 handover **without** SGW relocation	
11	Intra-MME X2 handover	
12	Inter-MME handover	
13	Intra-MME tracking area updates	
14	Inter-MME tracking area updates	

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What is MME Pooling?

- Number of MME's clustered in pool across geographical area
- MME is identified by Code & Group Identifier
- All MME in pool will have same Group identifier



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Benefits of MME Pooling

- Enables geographical redundancy, as a pool can be distributed across sites.
- Increases overall capacity, as load sharing across the MMEs in a pool is possible.
- Converts inter-MME Tracking Area Updates (TAUs) to intra-MME TAUs for moves between the MMEs of the same pool. This substantially reduces signaling load as well as data transfer delays.
- Eases introduction of new nodes and replacement of old nodes as subscribers can be moved is a planned manner to the new node.
- Eliminates single point of failure between an eNodeB and MME.
- Enables service downtime free maintenance scheduling.

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MME Paging Considerations

Signaling Storm – High Paging

- Idle mode paging causes volumes of signaling traffic
- Impacts radio network where paging is a common resource
- Ideally SGW do not discriminate among received packets
  - Any packet is page eligible
  - Signaling storms & drain mobile battery
  - In worst case, it may be an attack to bring the network down
  - May not be able to bill for delivery of unwanted packets
- Vulnerable to DoS and DDoS attacks
  - Need to qualify DL packets before page request initiation

Solution

- MME maintain list of mobile & eNB from which last registered
- Page selected eNB
- No response then page all eNB in Tracking Area ID
- Use selective & Application aware paging

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SGW/PGW Design Parameters

- SGW handle control & bearer, whereas PGW mainly handle bearer traffic
- SGW/PGW combo balance control & bearer traffic

	SGW/PGW Parameters	Typical values**
1	Number of Simultaneous active subs	
2	Number of subs using IPv4 (% IPv4 PDN)	
3	Number of subs using IPv6 (% IPv6 PDN)	
4	Number of subs using IPv4v6 (% IPv4v6 PDN)	
5	Number of bearer activation/deactivation per PDN/Hr	
6	Number of average bearer per PDN connection	
7	Number of PDN connection setup/tear down per sub/Hr	
8	Number of PDN session per sub	
9	Number of idle-active/active-idle transaction per sub/Hr	
10	Number of intra SGW handover per sub/Hr	
11	Number of Inter SGW handover per sub/Hr	
12	Number of inter-system handover per sub/Hr	

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SGW/PGW Design Parameters (Cont'd)

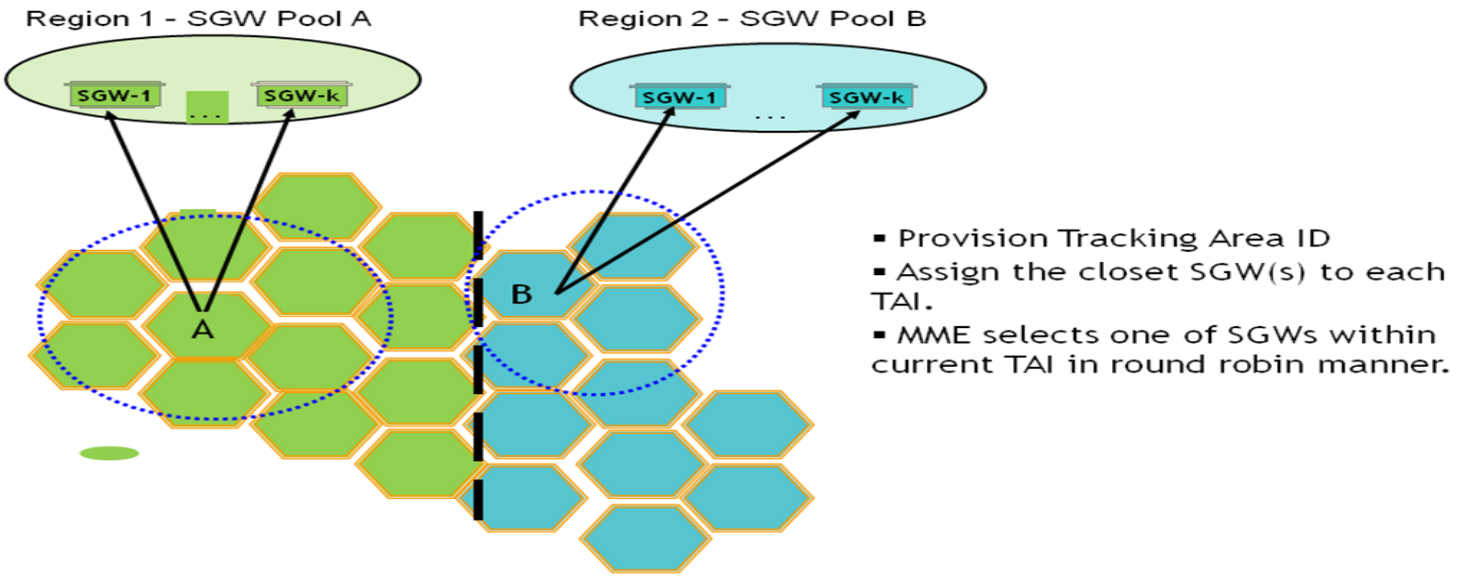
	SGW/PGW Parameters	Typical values**
	PCEF (Policy Control Enforcement Function) Design	
1	No of flow /subscriber	
2	% of deep flow inspection	
3	% of deep packet inspection	
4	% of PDN connection using Gy (pre-paid)	
5	% of PDN connection using Gx (Policy interface)	
6	Number of Gx Transactions per PDN Connection/Hr	
6	Number of Dynamic Rules	
	Data Subs Traffic	
1	% of subs simultaneously sending/receiving data	
2	Average packet size for DL	
3	Average packet size for UL	

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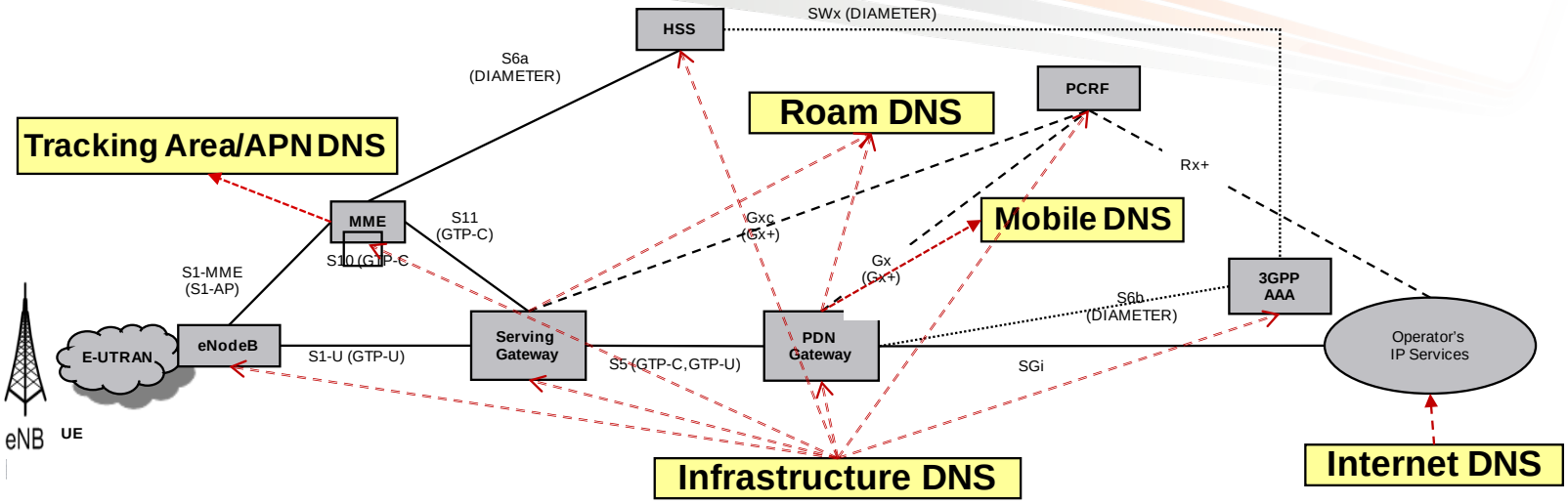
What is SGW Serving Area?

- Like MME; SGW's can also clustered as "serving area"
  - MME has greater option to select SGW
  - Reduce signaling overhead – inter SGW handover
- eNB have S1U link to multiple SGW in pool
- LTE UE is bear S1U only to one SGW
- Each SGW serving area has one Tracking Area Identifier (TAI)



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DNS Design

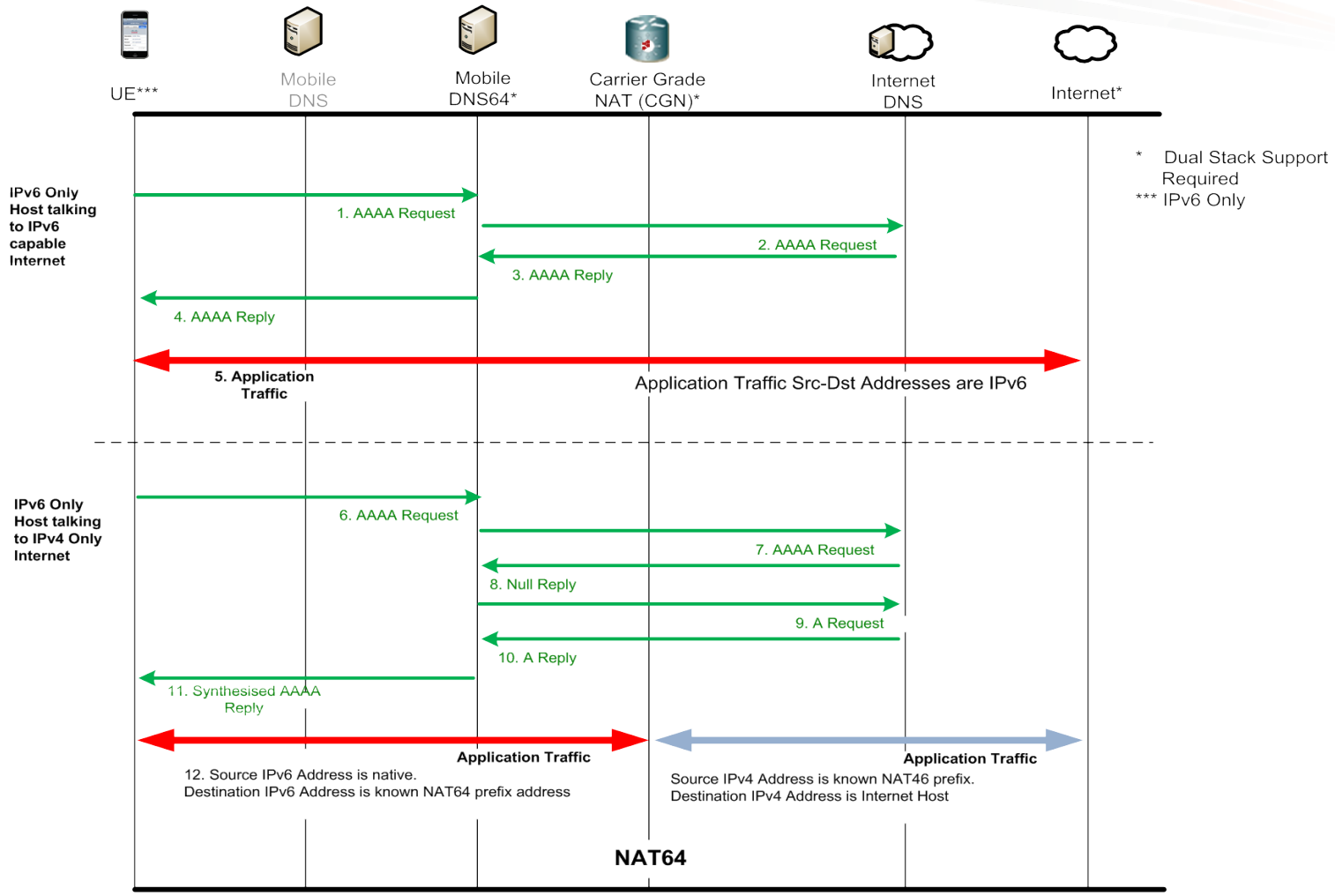


DNS	Functional description
Tracking Area/APN DNS	**Initial Attach** • MME perform APN query to find PGW, MME perform track Area query to find SGW **Handover with TAI change & Tracking Area Updates** • MME perform track query to determine SGW • MME select closest SGW to PGW send create session request
Mobile DNS	• LTE UE query mobile DNS to resolve "Host Name" to IP address • Can be DNS64 (LTE UE with IPv6), DNS44 (LTE UE with IPv4)
Internet DNS	• Mainly root DNS. Need DNS64 capability
Infrastructure DNS	• Name resolution in the OAM (e.g. admin to login to the device, SNMP)
Roam DNS	• Used for roaming traffic. Need IPv6 capability of roaming transport is IPv6

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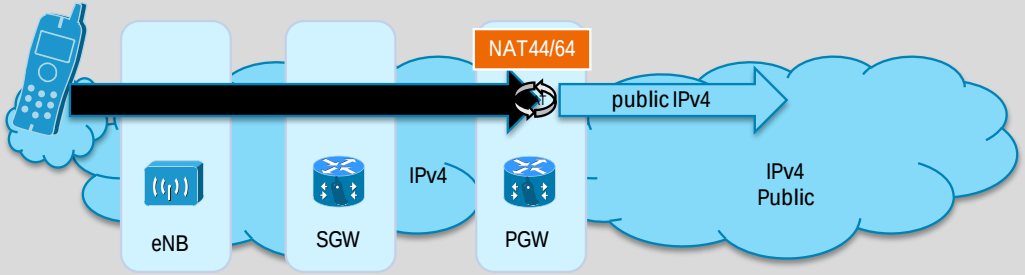
DNS64 Traffic Flow



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Large Scale NAT -Where to Place the NAT Function?

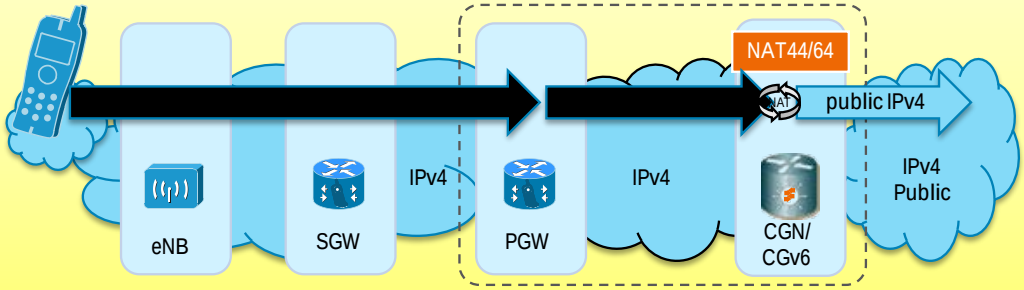
Option 1: NAT on Mobile Gateway (Distributed)



Key Benefits:

- Subscriber aware NAT
  - per subscriber control
  - per subscriber accounting
- Large Scale (further enhanced by distribution)
- Highly available (incl. geo-redundancy)

Option 2: NAT on Router (Centralized)



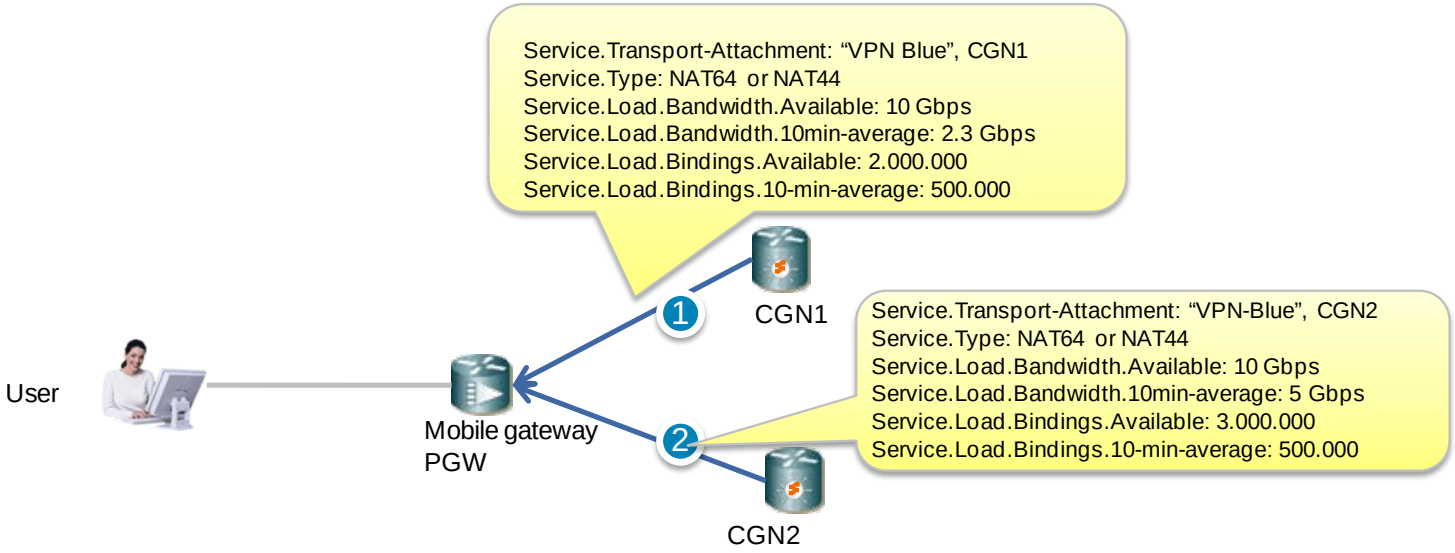
Key Benefits:

- Integrated NAT for multiple administrative domains (operational separation)
- Large Scale
- Overlapping private IPv4 domains (e.g. w/ VPNs)
- Intelligent routing to LSN

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Routing to Multiple CGN Gateways

FUTURE



- CGN announce their availability with dynamic state
- Mobile Gateway select the best route and forward traffic

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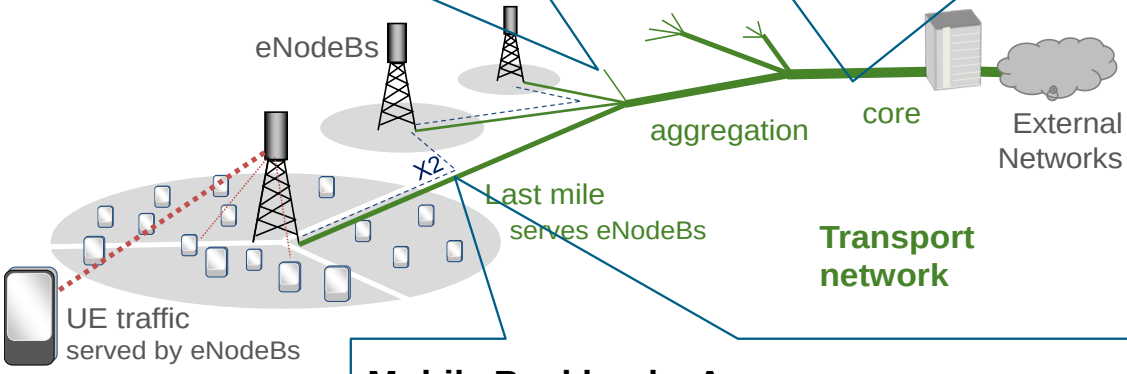
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Transport Planning – Mobile Backhaul, Core

Mobile Backhaul – Pre-agg/Agg
- Bandwidth- mean average with oversubscription
- Aggregating access and pre-agg rings
- Agile & resilient architecture to backhaul BW
- Routing- L2/L3VPN, Any-to-any routing

Core/Super backbone
- Bandwidth - mean average with over subscription
- Connecting backhaul from all regions
- Regional and National Datacenter
- Internet, roaming partners, Applications
- Routing – MPLS VPN/Global routing



Mobile Backhaul – Access
- Bandwidth- Full access capacity (Peak rate)
- Resiliency, failover, dual homing
- Routing - L2/L3 based on requirements.
- L3 is recommended

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Mobile Backhaul Design Requirements

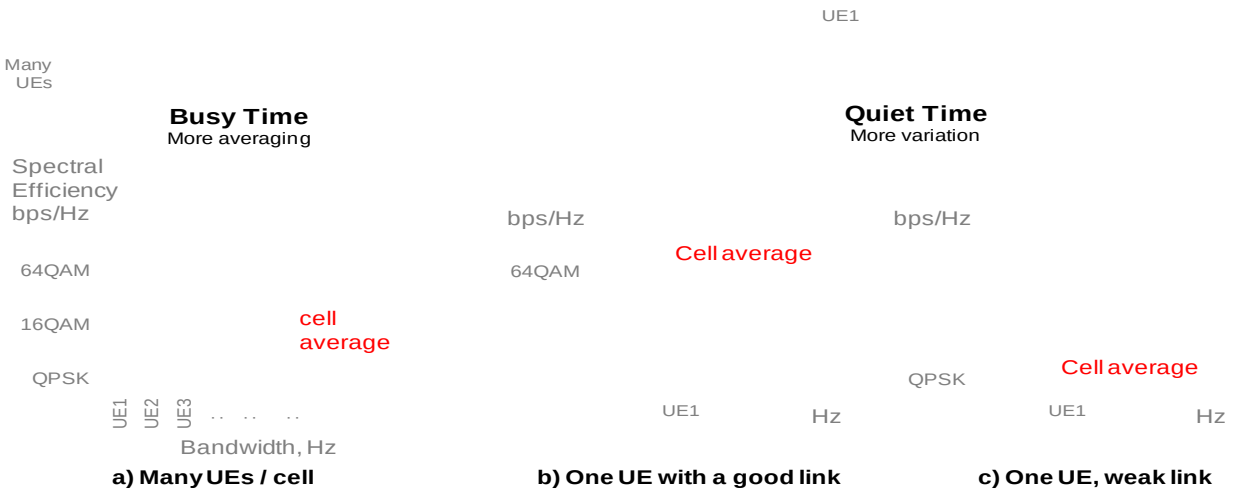
- **NGMN Alliance has released about 91 Requirements***
- eNB – Multi-homing to MME/SGW (S1-Flex), RAN sharing
  - Max 16 S1 interfaces, 6 operators (S1-Flex)
- Multicast Capability (eMBMS)
- QoS - QCI to DSCP/CoS mapping, Shape, Rate limit
- Bandwidth- LTE radio, other traffic (enterprise, WiFi)
- BW optimization, header compression etc
- Convergence support for 50 msec
- Remote Provisioning - Auto/Zero touch
- Clock distribution (Frequency, phase, time), Clock Recovery
- Control plane and data plane security
- Inter eNodeB X2 Traffic routing
- **Summary: any-to-any IP routing for unicast and multicast**

* NGMN- Next Generation Mobile Network (Alliance of Mobile service Providers)

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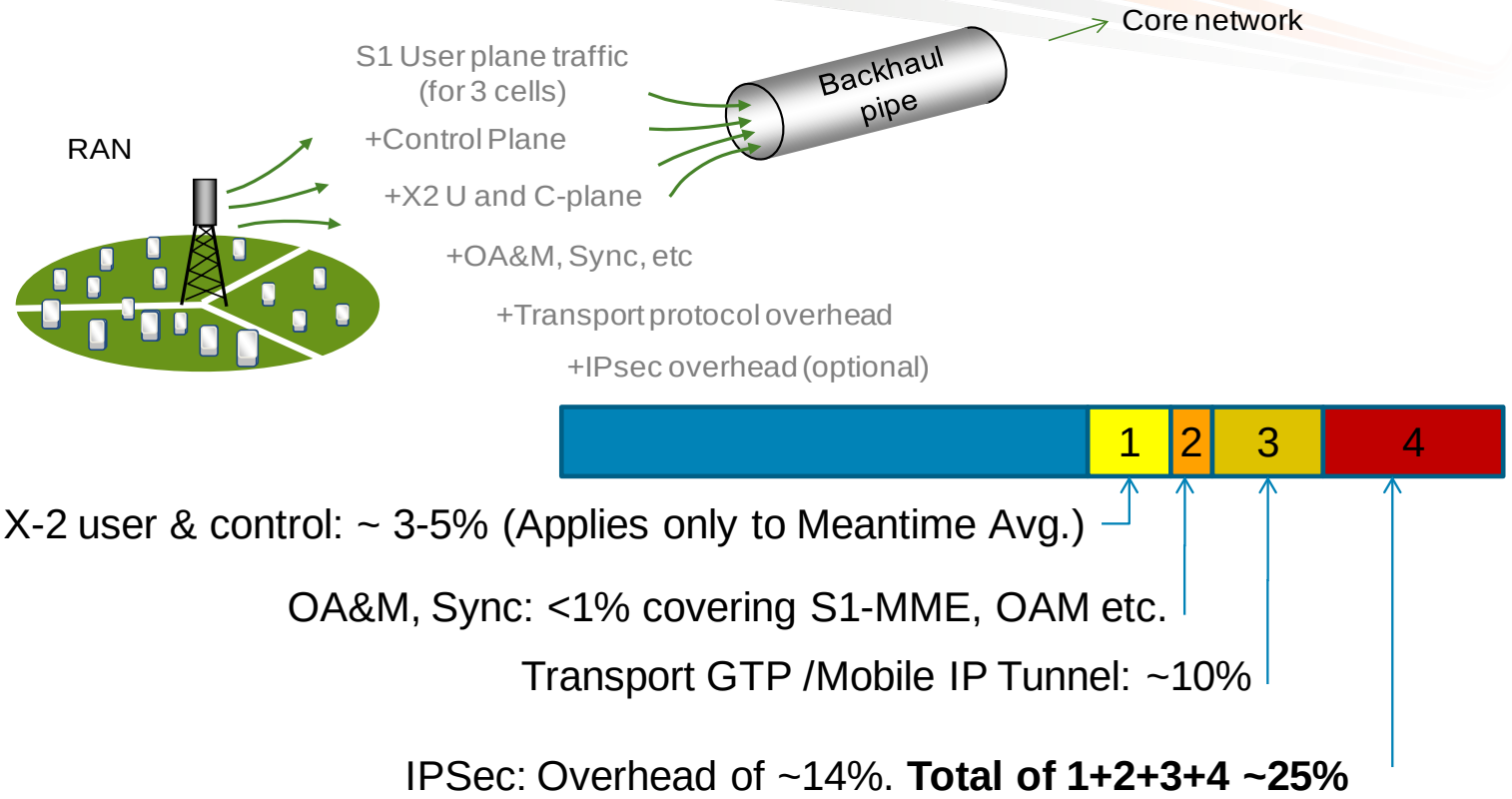
Mobile Backhaul Bandwidth - Radio Behavior

- BW is designed on per cell/sector, including each radio type
  - Busy time – averaged across all users
  - Quiet Time – one/two users (Utilize Peak bandwidth)
- For multi-technology radio- sum of BW for each technology
- Last mile bandwidth- Planned with **Peak**
- Aggregation/Core – Planned with **Meantime Average**
- Manage over subscription



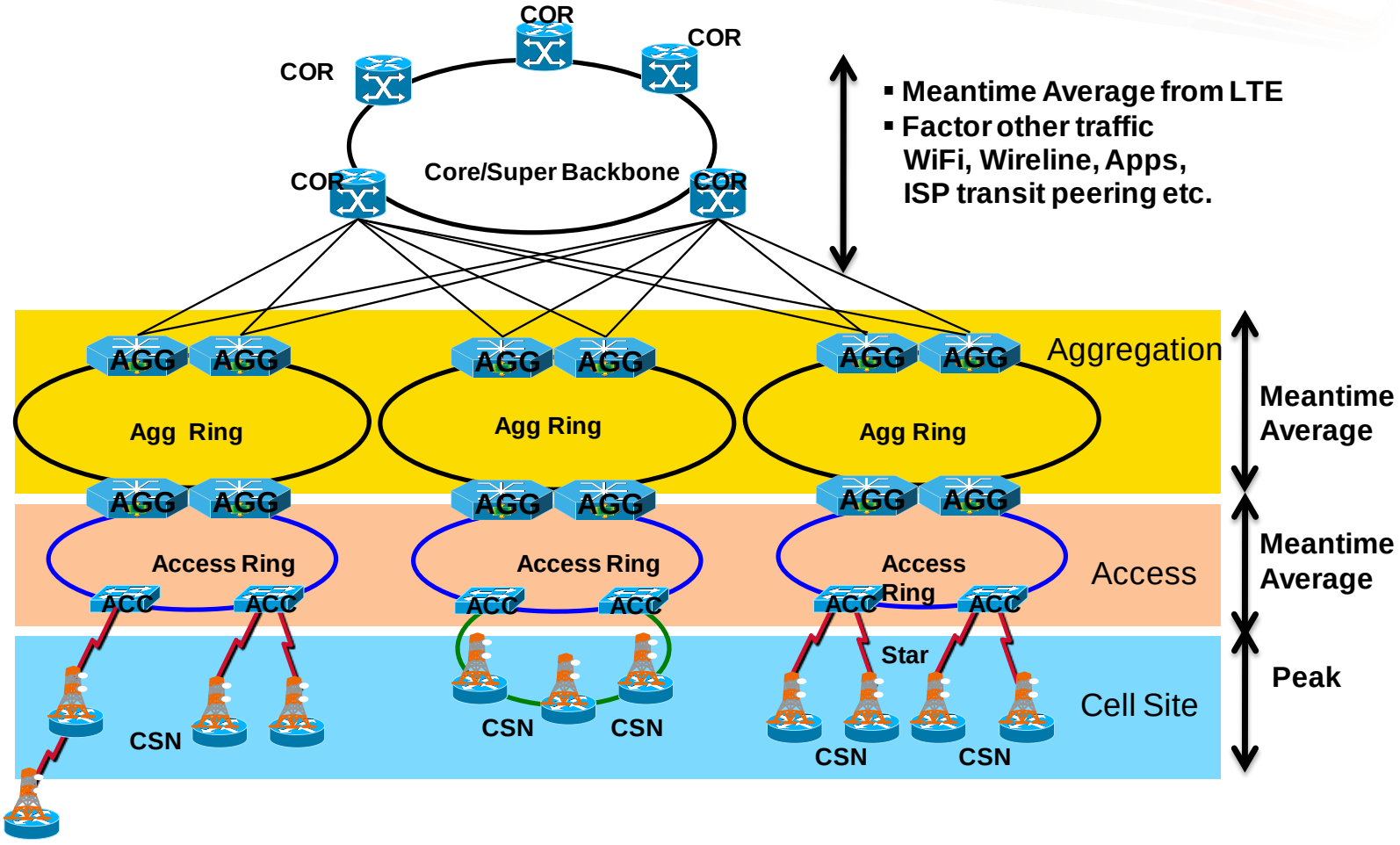
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Mobile Backhaul Bandwidth – Overheads



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Mobile Backhaul Bandwidth – Agg & Core



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Mobile Backhaul Bandwidth – Last Mile

Considerations

- Use quiet time peak for each cell
- Not all cells will peak at same time- Factor this for 3/6 sector eNB
- Microwave – Number of hops, total bandwidth
- Access ring will have dual homing to pre-agg

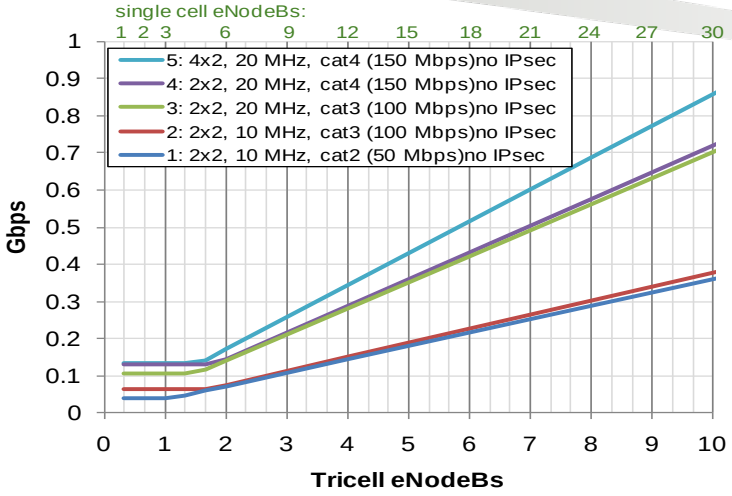
All values in Mbps								Total U-plane + Transport overhead			
Scenario, from TUDR study		Single Cell		Single base station		X2 Overhead		No IPsec		IPsec	
		Mean	Peak	Tri-cell Tput		overhead	4%	overhead	10%	overhead	25%
		(as load-> infinity)	(lowest load)	busy time mean	peak	busy time mean	peak	busy time mean	peak	busy time mean	peak
DL	1: 2x2, 10 MHz, cat2 (50 Mbps)	10.5	37.8	31.5	37.8	1.3	0	36.0	41.6	41.0	47.3
DL	2: 2x2, 10 MHz, cat3 (100 Mbps)	11.0	58.5	33.0	58.5	1.3	0	37.8	64.4	42.9	73.2
DL	3: 2x2, 20 MHz, cat3 (100 Mbps)	20.5	95.7	61.5	95.7	2.5	0	70.4	105.3	80.0	119.6
DL	4: 2x2, 20 MHz, cat4 (150 Mbps)	21.0	117.7	63.0	117.7	2.5	0	72.1	129.5	81.9	147.1
DL	5: 4x2, 20 MHz, cat4 (150 Mbps)	25.0	123.1	75.0	123.1	3.0	0	85.8	135.4	97.5	153.9
UL	1: 1x2, 10 MHz, cat3 (50 Mbps)	8.0	20.8	24.0	20.8	1.0	0	27.5	22.8	31.2	26.0
UL	2: 1x2, 20 MHz, cat3 (50 Mbps)	15.0	38.2	45.0	38.2	1.8	0	51.5	42.0	58.5	47.7
UL	3: 1x2, 20 MHz, cat5 (75 Mbps)	16.0	47.8	48.0	47.8	1.9	0	54.9	52.5	62.4	59.7
UL	4: 1x2, 20 MHz, cat3 (50 Mbps)*	14.0	46.9	42.0	46.9	1.7	0	48.0	51.6	54.6	58.6
UL	5: 1x4, 20 MHz, cat3 (50 Mbps)	26.0	46.2	78.0	46.2	3.1	0	89.2	50.8	101.4	57.8

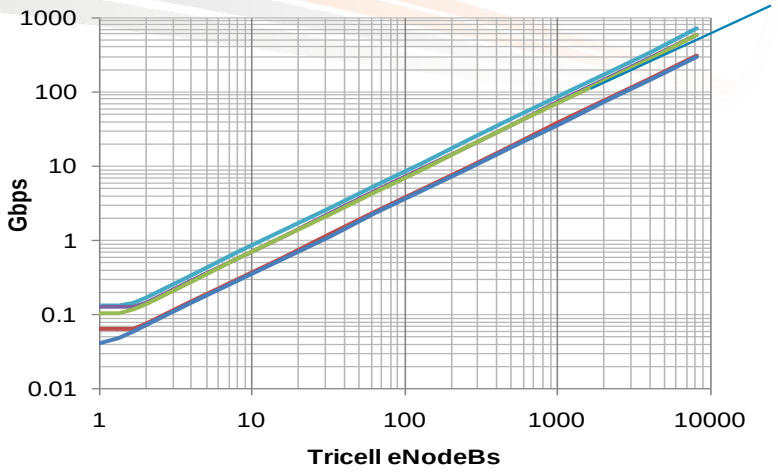
Total BW = DL + UL (20MHz, 2X2 DL MIMO, 1X2 UL MIMO) 105.3+42 ~ 145 Mbps

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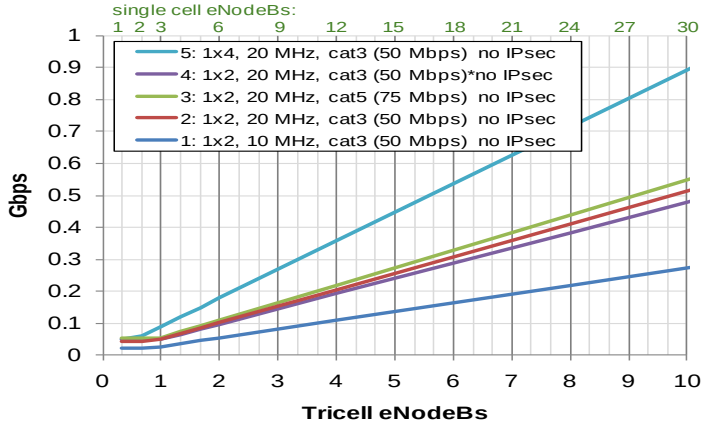
Mobile Backhaul Bandwidth – Agg & Core

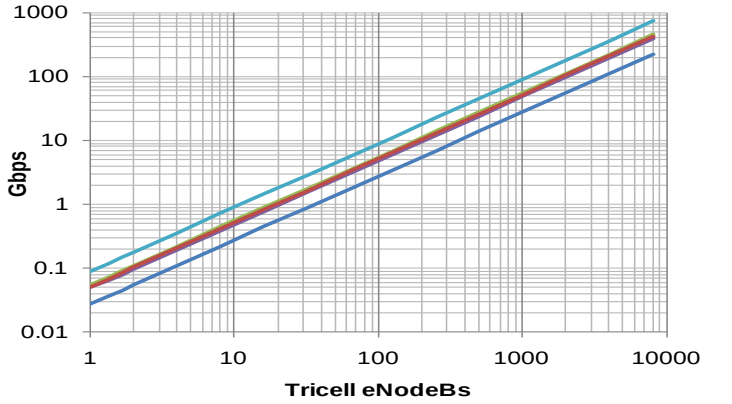
Down link





Uplink





Total BW = DL + UL ; For 10,000 eNB (Tricell) = 700+500 = 1200 Gbps
Per eNB in Core ~ 1200/10,000 ~ 120 Mbps

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Agenda

- Mobile Broadband Dynamics
- Mobile Network Evolution
- LTE Architecture Framework
- **LTE Design Strategies**
  - Latency & Delay
  - IP Planning
  - MME, SGW/PGW, DNS, HSS, PCRF
  - Transport Planning – Backhaul, MPLS Core
  - **Security Framework**
- LTE Deployment Strategies
- Summary, References

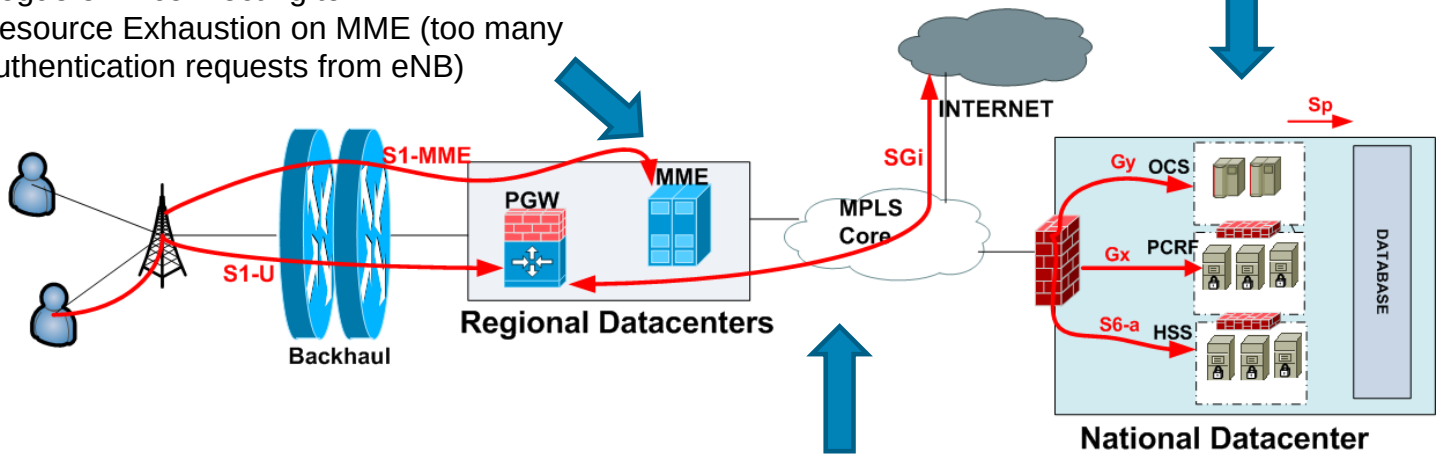
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LTE Network Security Threats

- Rogue MME connecting to HSS or PCRF
- HSS, PCRF protections against DOS/DDOS attacks
- Database (Sp) must be protected against protocol anomalies attacks like SQL Slammer worm or resource consumption attacks.
- CDR protection against manipulation by both internal or external attackers.

- Rogue eNB connecting to RIL MME.
- Resource Exhaustion on MME (too many authentication requests from eNB)



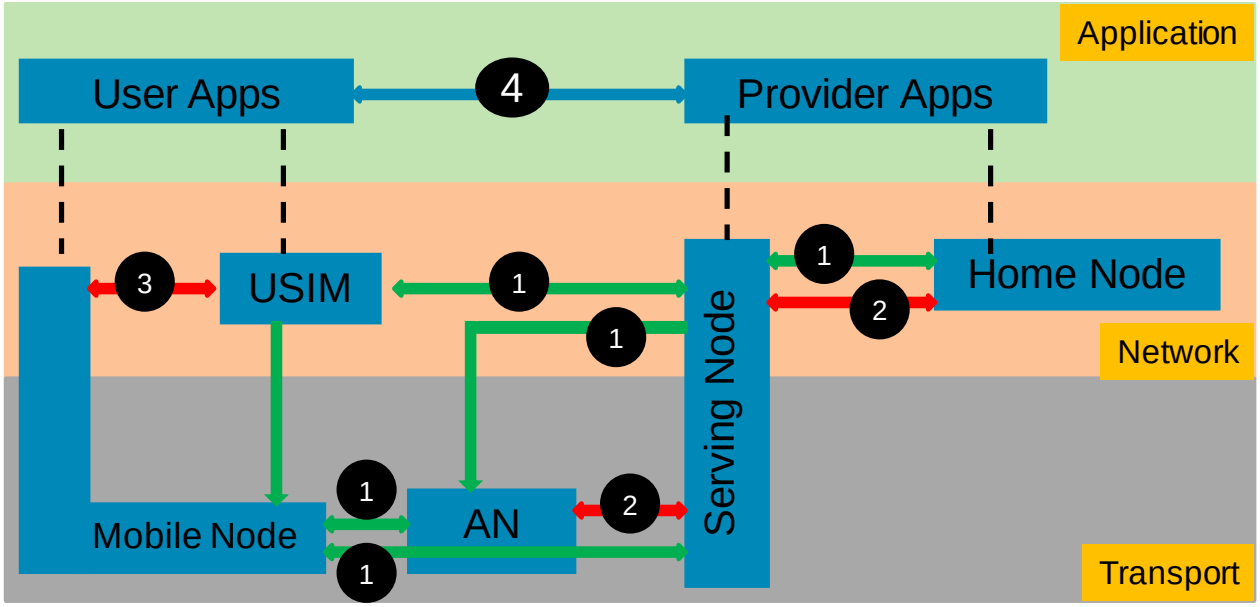
- Mobile to Mobile Spewing Attacks
- DOS Attacks in downlink direction from Internet
- TCP based attacks from Internet (Syn, session hijack, resource exhaustion etc.)
- UDP Based attacks like Smurf attack.
- ICMP Attacks like ping of death. Fragmentation attacks.
- Layer 4 protocol anomalies attacks
- Malware/Spyware prevention

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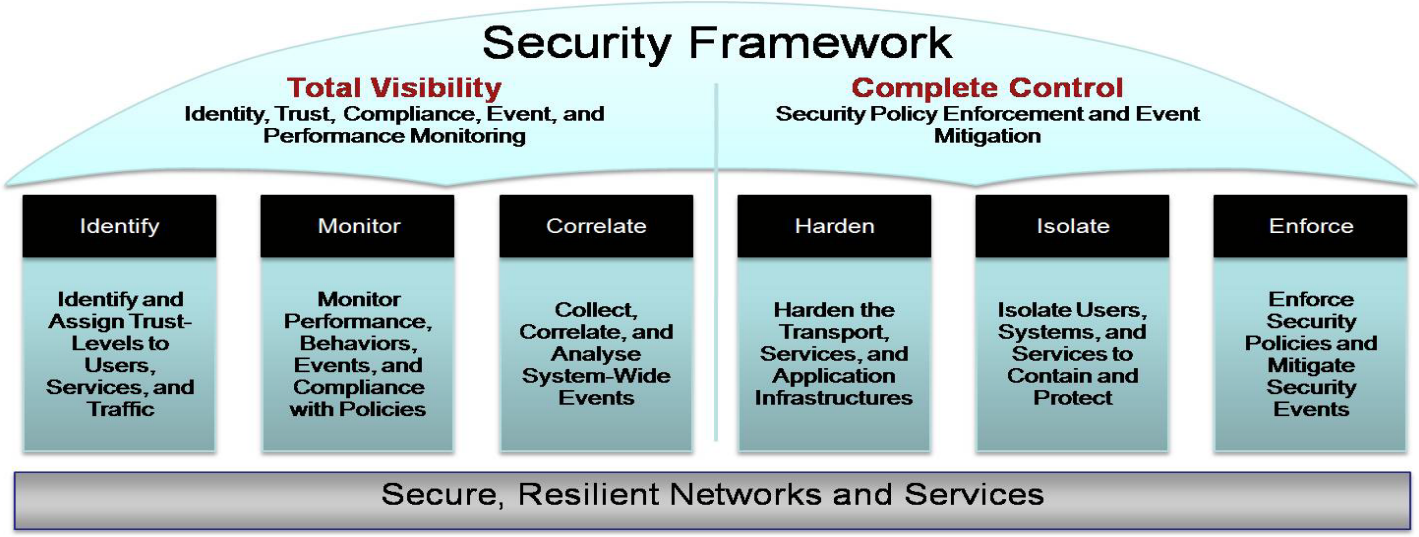
3GPP TS 33.401 Security Standards

1	Network Access	Security in Radio Access
2	Network Domain	Network security for signaling & user data
3	User Domain	Security for mobile
4	Application Domain	User & Apps security



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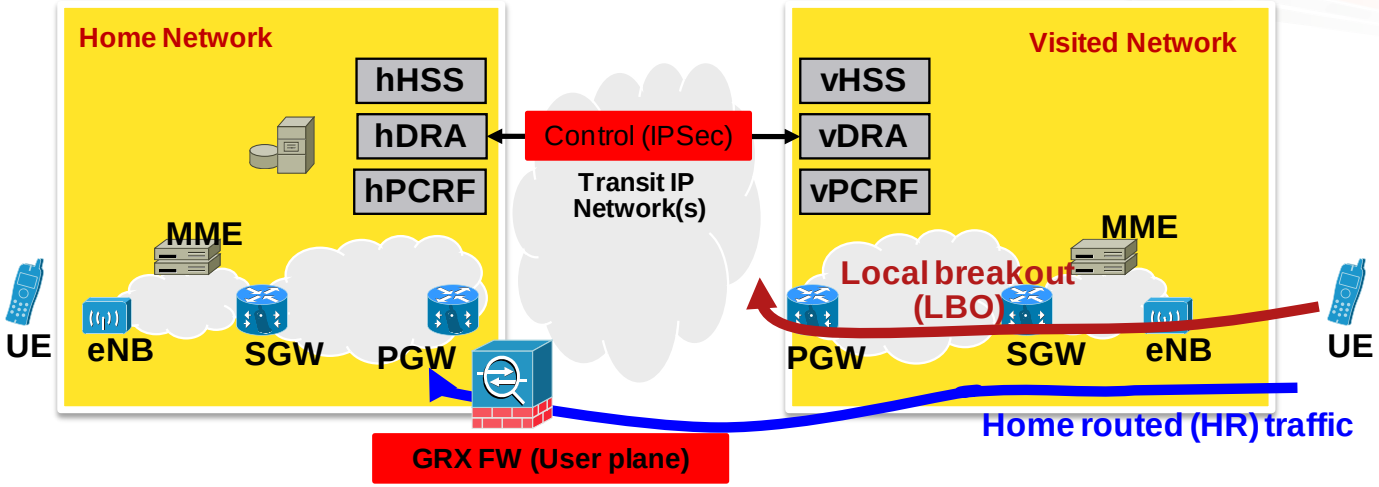
SP Security Framework - COPM



Framework	Recommendations
Identity	LTE users (AAA and PCRF), Routing Authentication
Monitor	PCEF/PCRF, IPS, Probes, Netflow, NBAR, Topology Map, DOS, DDOS
Correlate	Security Operations Center (collect, correlate security incidents and alerts)
Harden	Control Plane Policing, VTTY lockdown, NTP, syslog, config mgmt
Isolate	Contexts, Virtualization, Remote Triggered BlackHole
Enforce	iACL, ACLs, Firewall, uRPF, QoS, Rate Limiting

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Security for Roaming Traffic



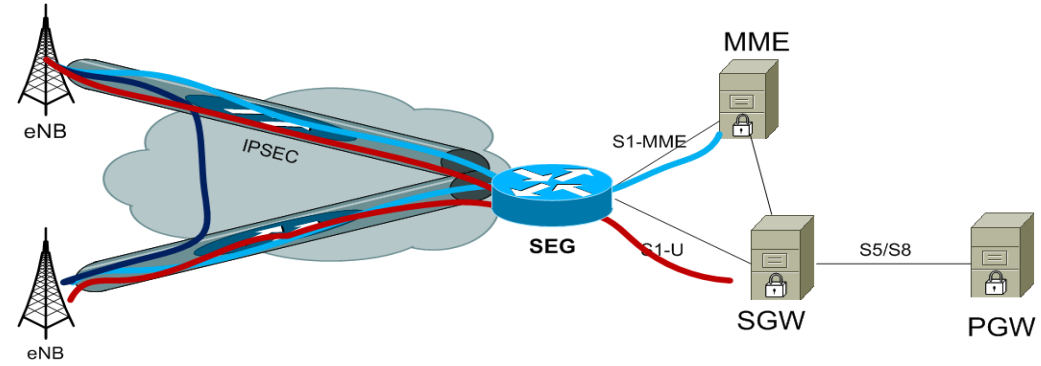
- IPSec tunnel between hDRA and vDRA to route control traffic
  - User authentication traffic between vHSS and hHDSS
  - Policy traffic between hPCRF and vPCRF
- GRX firewall to for user plane romaing traffic
- For local breakout visited network provide internet security

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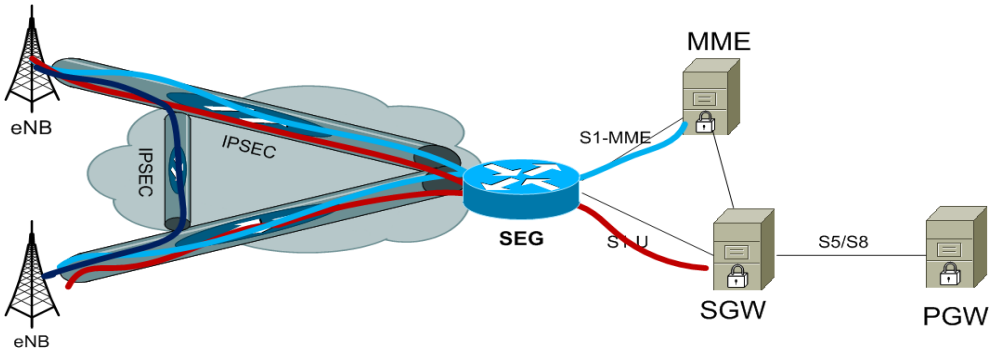
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Security for Backhaul

- 3GPP specifies IPSec for security Gateway for backhaul traffic
- For RAN sharing Security gateway is must
- IPSec will add overhead (~ 25%), Provision additional bandwidth
- Many variations – S1-MME, S1-U, X-2, Management



X-2 is routed directly at access ring.
Layer-3 at Cellsite Node



X-2 is routed through shared RAN (Agg/Core) using IPSec tunnel

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  - Transport Planning – Backhaul, MPLS Core
  - Security Framework
- **LTE Deployment Strategies**
- Summary, References

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LTE Deployment Strategies

Plan and Design [Getting ready]

- IP Transformation- LTE readiness Assessment
- Skillet – IPv6, LTE technology Trainings
- Radio planning – site acquisition/readiness
- Business Planning – services, subscribers
- E2E LTE Design: Radio, Transport, Gateways, Datacenter, Apps

Test and Validation [Technology Validation]

- E2E System integration and testing
- System level IOT- All vendors, All related elements, All Apps
- IRAT testing - 2G/3G; Offload – WiFi, Femto
- Device ecosystem testing, Apps testing
- Roaming testing with other LTE networks

Field Trials, Friendly Users [Getting ready to Deploy]

- E2E network validation with real users
- KPI, Ops and troubleshooting tools,
- NOC, OSS/BSS - Support structure

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LTE Deployment Strategies

Scaling in Deployment

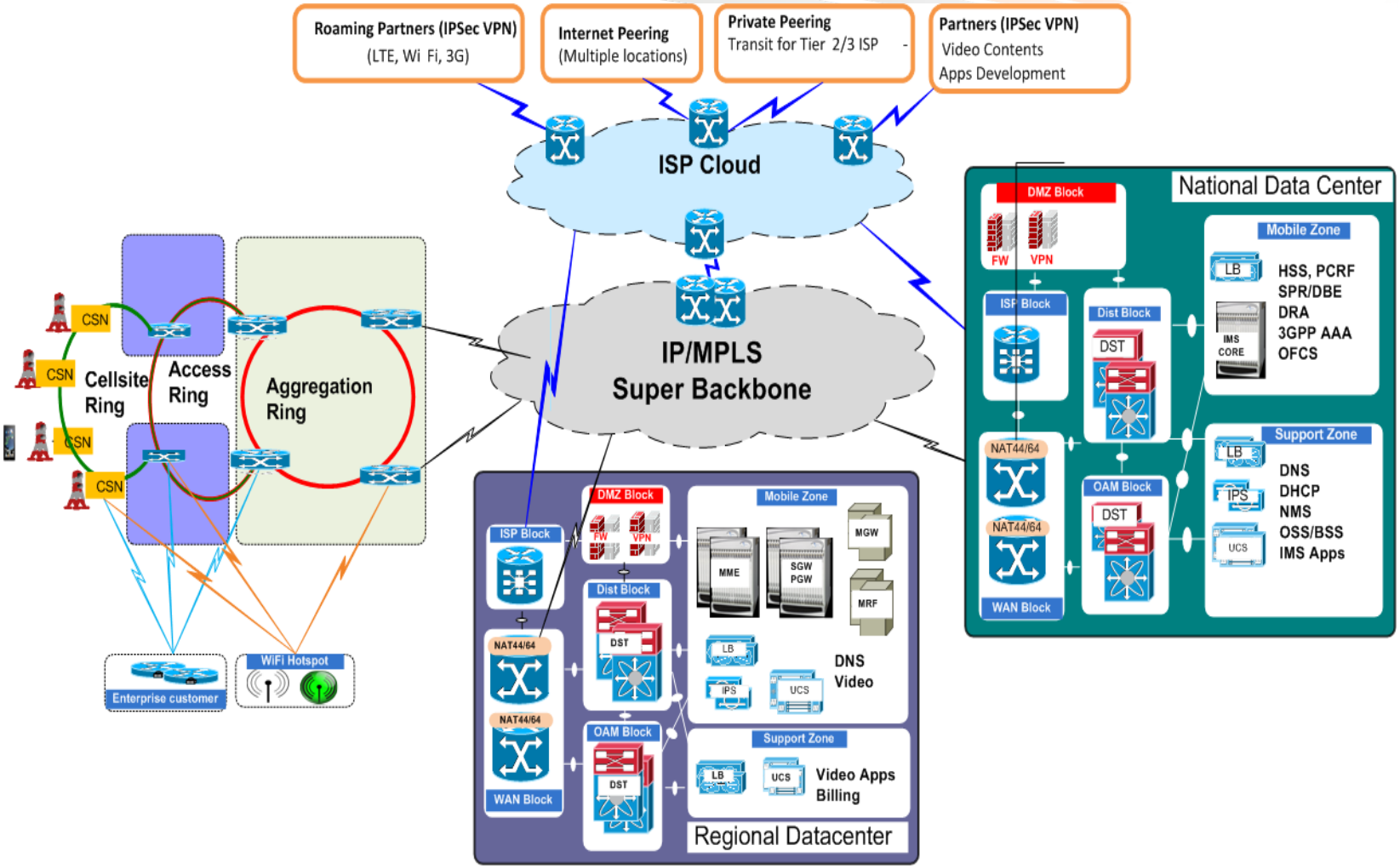
- Implementation Plans – Integration and Test automation
- Scaling the architecture - Traffic Modeling, Virtualization
- Tools development - Provisioning, Monitoring, IPv6
- Knowledge Enhancement - Engineering and Ops

Operations and Optimize

- NOC- E2E IP infrastructure, centralized FCAPS
- Centralize & automated IP Management
- Security Operations (SOC)- consistent security implementation
- Organization realignments – Engineering, Operations
- Asset Lite, partner collaboration strategy

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Everything Put Together – How Does It Look?

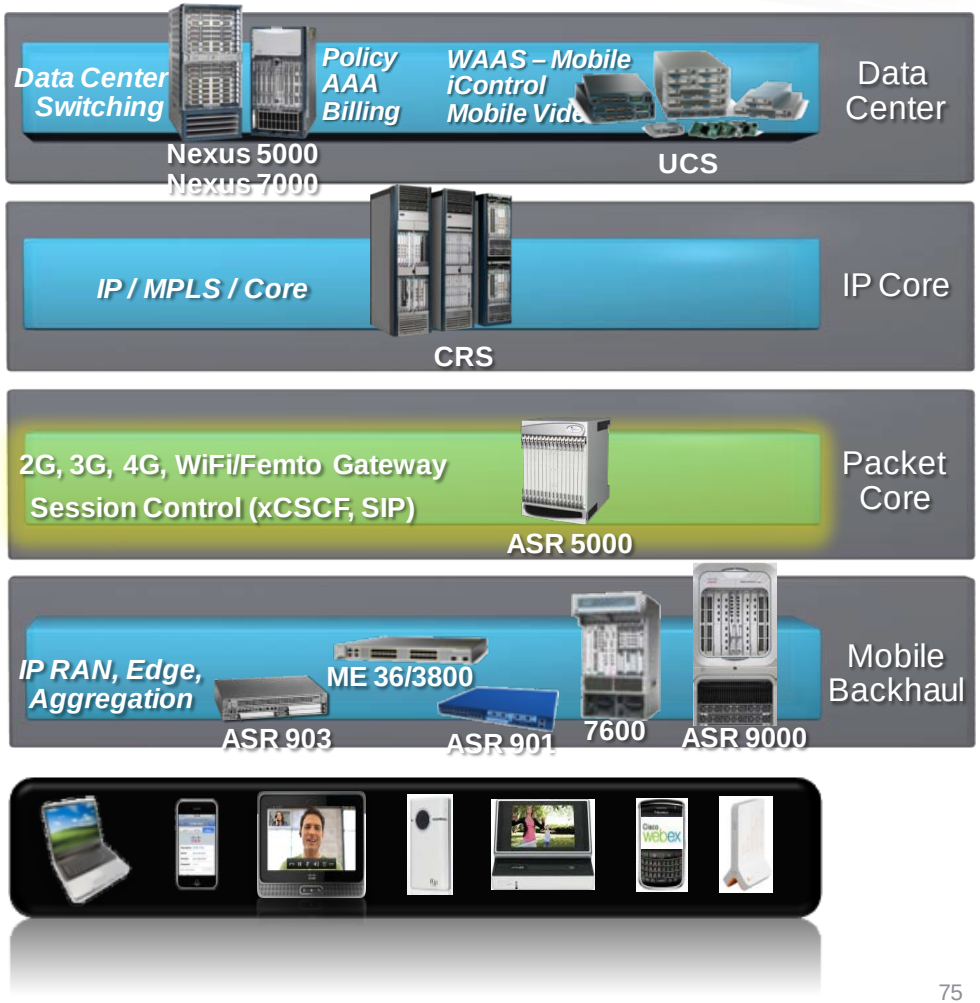


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Cisco EPC: Intelligent Performance

One Network, Any G, Any Screen

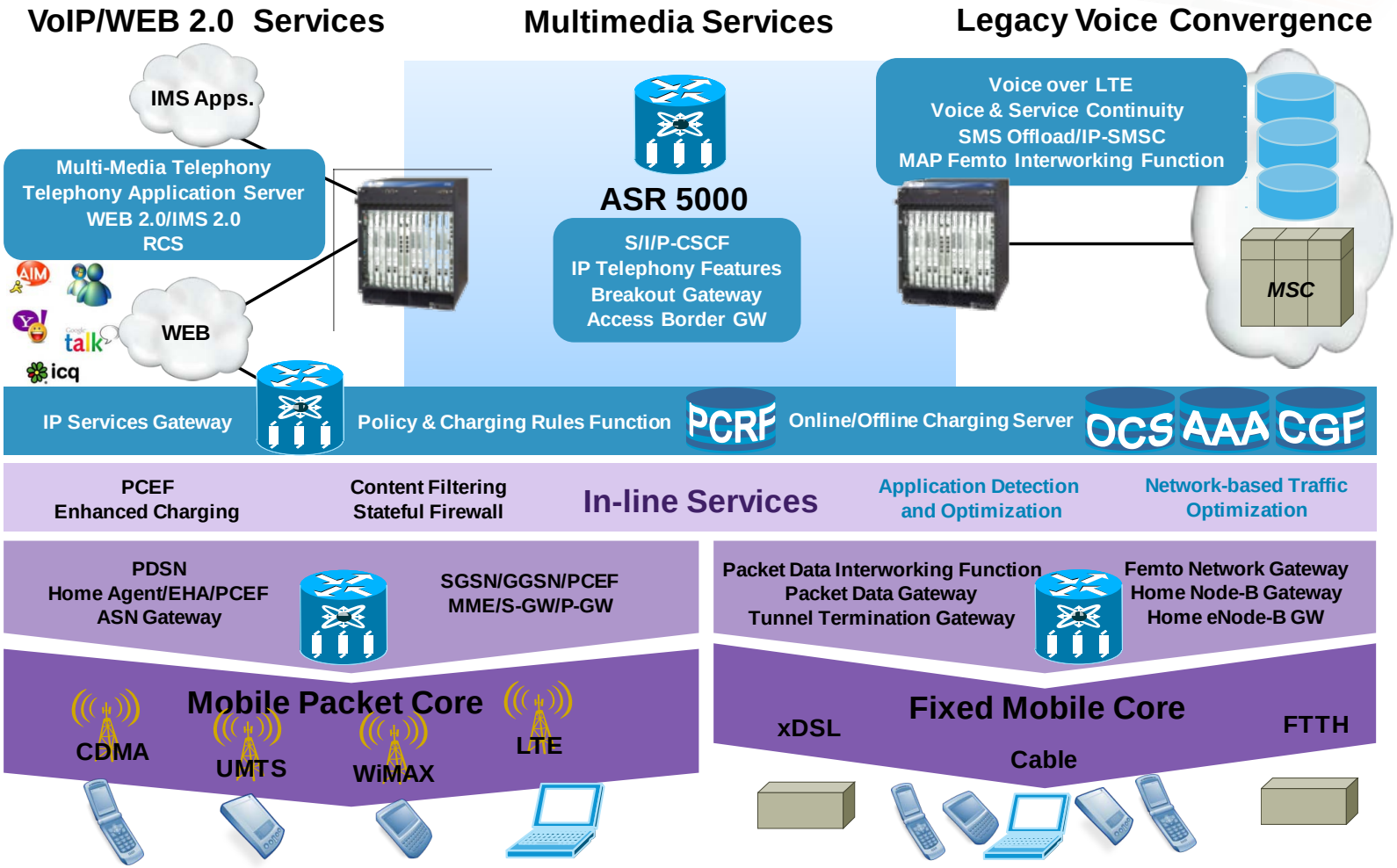
- Comprehensive
- Flexible
- Powerful Performance
- Highly Intelligent



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Evolution of Cisco's MITG Portfolio
Multimedia Services



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Cisco MITG ASR 5000 Product Line

Software Decoupled from Hardware

Software Functions

In-Line Services, GGSN, HA, PCRF, PDSN, SCM, SeGW, SGSN, ASN GW, MME, SGW, PGW, HNB-GW, HeNB-GW

Hardware Platforms

ASR 5000 Mobile Multimedia Platforms



ASR 5000

Performance & Scalability

- Software functions work across multimedia core platforms
- Platform decision based on performance not function
- All multimedia core platforms support EPC, 3G, etc.
- Next generation product line

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   3GPP Release 10 and beyond
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   GSN-UMTS migration to 4G
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   3GPP TR 36.913 Requirement for E-UTRA and E-UTRAN
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   3GPP TR23.975 IPv6 Migration Guidelines (R10)
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