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Spectrum Sharing Between Public Safety and Utilities

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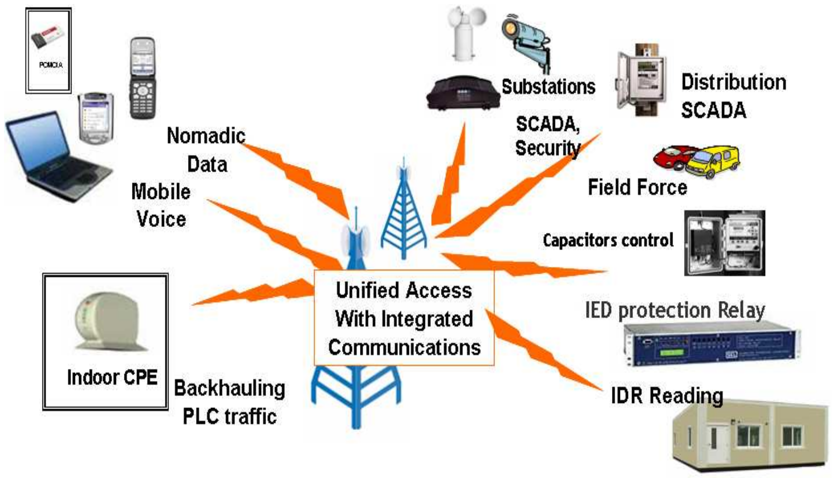
A Vision of the Smart Grid Wireless Communications Infrastructure

- Up to 5-10 Mb/s of Highly Secure, Uninterruptable and Ubiquitous Broadband Wireless Connectivity
- Guaranteed Service (99.999%) during
  - ✓ Force Majeure Circumstances
  - ✓ Extended Power Outages (days/weeks, not hours)
  - ✓ Homeland Security Events
  - ✓ Other High Telecom Traffic Events (e.g. Football Games)



- Integrates LAN, NAN, and WAN technologies seamlessly
- Designed for any mix of Voice/Data/Video applications
- Roadmap to Secure Private Channel and Group Broadcast Voice
- Supports Fixed, Mobile, and Nomadic Broadband Data
- Control: the Utility determines traffic priority via QoS for its business
- Future-Proofing: Utilities expect 15-20 years of life from a private solution
- Security: the solution will be built and managed to the Utility’s own security policies
- Operations: Highly automated diagnostics correlating grid, IT and network events
- Based on open standards

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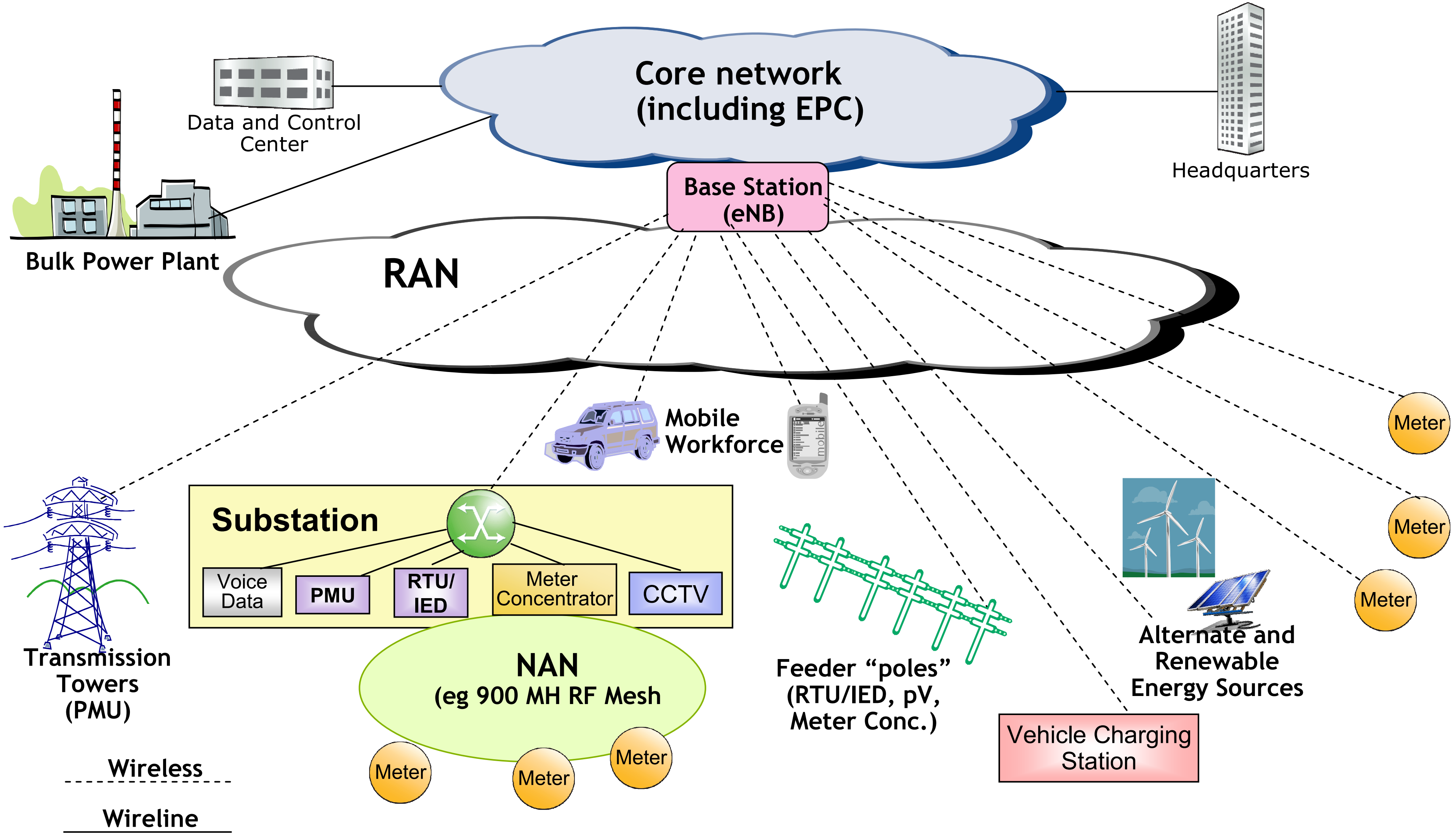
Utility LTE Reference Architecture



Key Assumptions

- Utility data and control centers and other large locations connect to the EPC over *wireline* networks
- Traffic worst case for a cell (or eNB) is used for bandwidth computation
  - For example, almost all transmission, distribution, DER, mobile work force, and other substation traffic is carried over wireless network
  - Where accurate inputs are unavailable, reasonable worst-case values are used
- Only uplink (from end system *to* base station) traffic is computed
  - For utility applications the total downlink traffic is rarely more than the total uplink traffic
  - In most wireless installations, downlink capacity is significantly more than the uplink capacity
- Expected developments in the smart grid evolution in the next few years are included. For example,
  - All meters are smart meters capable of two way communication for AMI
  - In addition to the substations, synchrophasors will be deployed at (some) transmission towers
  - SCADA RTUs/IEDs will be deployed at many feeder locations outside of the substation
  - Deployment of alternate and renewable sources of energy as well as electric vehicle “charging stations” requiring communication in the smart grid
- All voice traffic (push to talk as well as person-person) is VoIP

Applications

- **(Traditional) SCADA**
  - Normal: Periodic measurements from RTUs/IEDs in substations and at feeder points outside of substation, other SCADA traffic
  - Critical: Periodic measurements from RTUs/IEDs in substations and feeders
- **Synchrophasors**
  - Normal: Class A periodic measurements from PMUs in substations and feeders, Class C and other traffic
  - Critical: Class A periodic measurements from PMUs in substations and feeders,
- **CCTV**
  - Normal: low speed video streams from all surveillance cameras at substation
  - Critical: High speed video stream from one camera in one substation and low speed streams from all other cameras
- **Mobile workforce**
  - Normal: Push to talk for one talk group.
  - Critical: Push to talk for multiple talk groups, real time video stream from an incidence
- **AMI**
  - Normal: Periodic meter measurements (directly from the meter or meter conc. as the case may be)
  - Critical: Meter registration traffic from (a percentage of) meters after blackout
- **New Smart Grid Element (DER, vehicle charging stations, etc)**
  - Normal: Measurements from RTUs/IEDs, other traffic
  - Critical: Measurements from RTUs/IEDs
- **Enterprise VoIP: Substation personnel, non PTT mobile workforce**
  - Normal: Low demand (in Erlang)
  - Critical: High demand (in Erlang)
- **Enterprise Data: Substation personnel, non PTT mobile workforce**
  - Normal: Busy hour traffic
  - Critical: Equal to busy hour traffic

Individual Application Traffic*

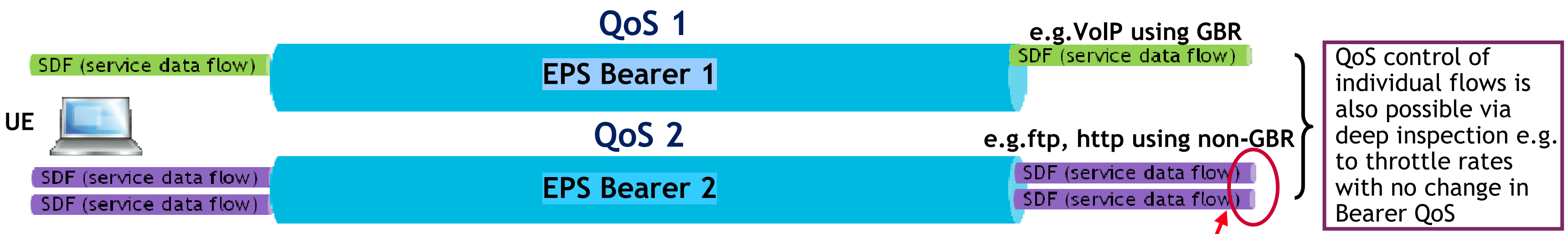
Traffic Req. in kbps		Scenario 1 Dense Urban area **with** meter concentrators	Scenario 2 Dense Urban area **without** meter concentrators	Scenario 3 Urban area **with** meter concentrators	Scenario 4 Subarban area **with** meter concentrators	Scenario 5 Rural area **without** meter concentrators
Total	**Normal**	**1,651**	**1,722**	**1,504**	**1,630**	**3,302**
	Critical	**3,439**	**3,426**	**3,112**	**2,936**	**4,321**
Traditional SCADA	Normal	165	165	95	140	236
	Critical	138	138	79	116	98
Synchr-ophasors	Normal	221	221	221	331	993
	Critical	182	182	182	272	817
CCTV	Normal	826	826	826	826	1,651
	Critical	1,238	1,238	1,238	1,238	2,064
Mobile WF (PTT - VoIP)	Normal	16	16	16	16	16
	Critical	161	161	129	81	81
Mobile WF (video)	Normal	0	0	0	0	0
	Critical	550	550	550	550	550
AMI	Normal	154	225	77	77	139
	Critical	154	140	77	77	86
New Smart Grid Elements	Normal	32	32	32	48	64
	Critical	27	27	27	40	54
Enterprise VoIP	Normal	113	113	113	97	97
	Critical	435	435	371	274	274
Enterprise Data	Normal	124	124	124	96	105
	Critical	554	554	459	287	296

* Using "rough order of magnitude" computations based on worst case assumptions and simple models assuming cell average uplink (10+10) = 18Mb/s, downlink = 36Mb/s in a 3 sector cell

EPS QoS Parameters

<u>Per bearer</u> (or bearer aggregate) QoS parameters:

- QoS Class Identifier (QCI)
  - A scalar that is used as a reference to node-specific parameters that control packet forwarding treatment (e.g. scheduling weights, admission thresholds, queue management thresholds, link layer protocol configuration, etc.), and that have been pre-configured by the operator owning the node, e.g. eNodeB
- Allocation and Retention Priority (ARP) ← **For admission control, i.e. not used by eNodeB scheduler**
  - The primary purpose or ARP is to decide if a bearer establishment/modification request can be accepted or rejected in case of resource limitation
- Maximum Bit Rate (MBR) – Per GBR bearer
- Aggregate Maximum Bit Rate (AMBR) – Sums all <u>non-GBR</u> bearers per terminal/APN



all flows get similar treatment (scheduling policy, queue management policy, etc.)

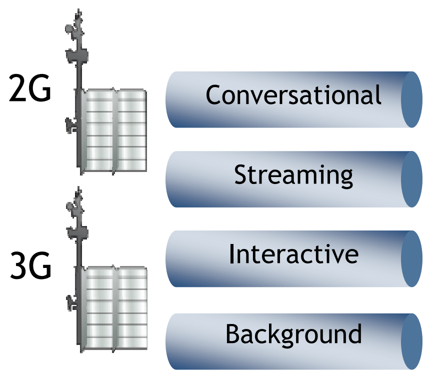
Traffic Filter Templates at both UE and PGW are responsible for distributing SDFs between EPS bearers

Bearer level QoS parameters are always assigned by the EPC

☐ MME or eNB cannot modify the bearer level QoS parameter values

☐ QoS parameter values can, however, be modified by the EPC

QoS Standardized QCI Characteristics*



SDF priorities

Maximum between PCEF and UE

QCI	Resource Type	Priority	Packet Delay Budget	Packet Error Loss Rate	Example Services
1	**GBR**	2	100 ms	10^{-2}	Conversational voice
2	**GBR**	4	150 ms	10^{-3}	Conversational video (live streaming)
3	**GBR**	3	50 ms	10^{-3}	Real-time gaming
4	**GBR**	5	300 ms	10^{-6}	Non-conversational video (buffered streaming)
5	**Non-GBR**	1	100 ms	10^{-6}	IMS signaling
6	**Non-GBR**	6	300 ms	10^{-6}	Video (buffered streaming) TCP-based (e.g., www, email, chat, ftp, p2p file sharing, progressive video, etc.)
7	**Non-GBR**	7	100 ms	10^{-3}	Voice, video (live streaming), interactive gaming
8	**Non-GBR**	8	300 ms	10^{-6}	"Premium bearer" for video (buffered streaming) TCP-based (e.g., www, email, chat, ftp, p2p file sharing, progressive video, etc.) for premium subscribers
9	**Non-GBR**	9			"Default bearer" for video TCP-based services, etc. for non-privileged subscribers

From: 4 classes in UMTS and CDMA
To: **9 classes (QCI) in LTE**

*Standardizing QCI characteristics ensures minimum level of QoS for mapped applications e.g. in case of roaming or with multi-vendor equipment

Priority Access

Distinction between ARP and QCI Priority

- ARP impacts Call Admission Control while QCI Priority impacts air-interface scheduler decisions

ARP bit pattern of a particular bearer's QoS indicates its Preemption Vulnerability, Preemption Capability and Priority level

- 15 Priority levels
- Vulnerability: can be preempted by a higher-priority bearer/UE
- Capability: can preempt a lower-priority bearer

ARP procedure is triggered upon radio congestion or capacity overload

- Start from lower priority and most vulnerable radio bearers or UE

GBR set up to congestion point, then ARP Pre-emption begins shedding load based on ARP level

MBR and AMBR can be set to apply only during congestion

Example Utility Application Priority Characteristics

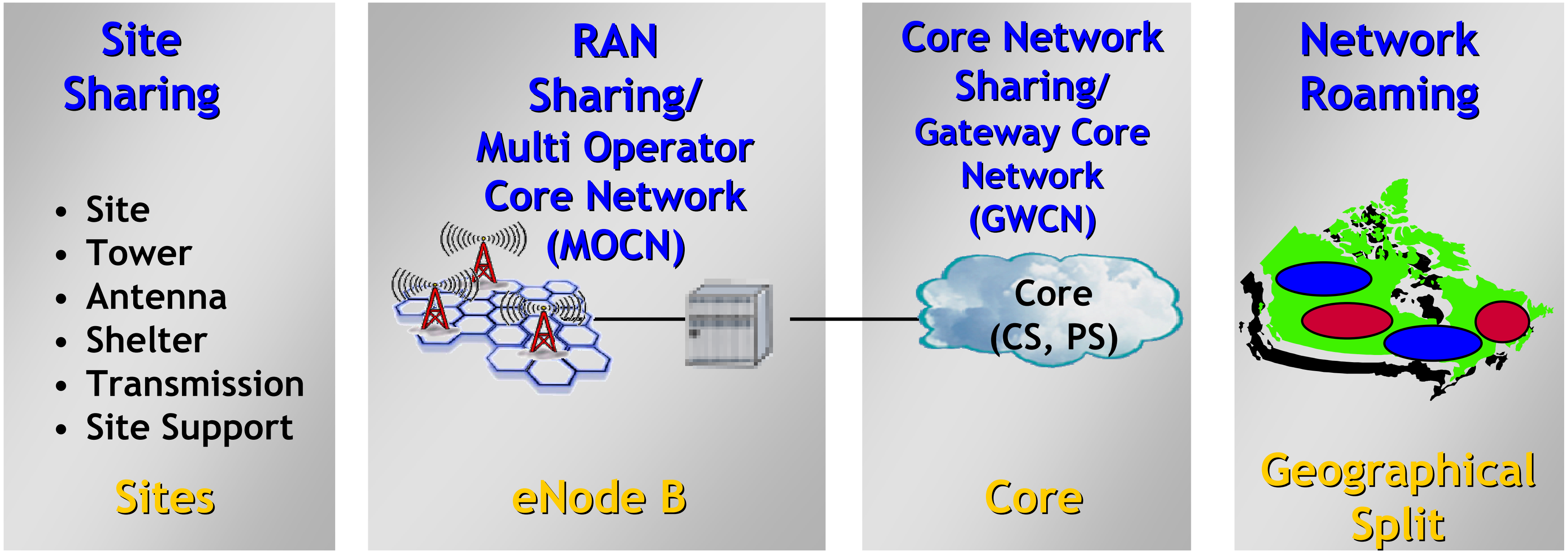
Application	GBR	QCI	ARP	MBR	AMBR
Traditional SCADA	Yes	2	High	2-20kb/s	N/A
Synchro-Phasors	Yes	6	Med High	~300kb/s	N/A
CCTV	No	9	Low	N/A	500kb/s
MWF VoIP PTT*	Yes	2 & 3	Med High to High	24kb/s	
MWF Video **	No & Yes	9 & 2	Low to Med High	256kb/s	500kb/s
AMI	No	9	Low	N/A	225kb/s
New SGE	No	6	Low	N/A	100kb/s
Ent. Voice	Yes	3	Med	400kb/s	N/A
Ent. Data	No	9	Med Low		500kb/s

* Multiple bearers with different priority levels dependant on bearer requirements (e.g emergency voice gets high ARP, normal PTT med ARP)

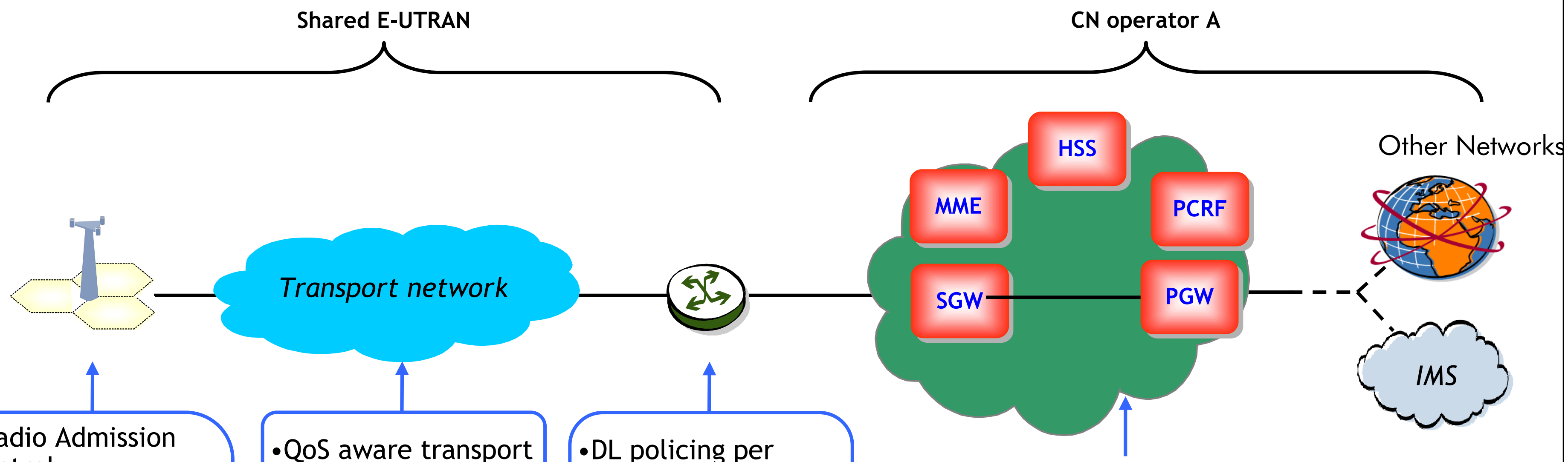
** Normal operations assumes little to no (best effort) MWF video. Critical operation raises priority, but can be rate limited.

A wide range of Infrastructure Sharing models in Mobile Networks

- **Site sharing model**
  - Site and Site support cabinet/rack sharing
  - Sharing of other elements such as mast/tower, antenna, shelter, transmission
- **Radio Access Network sharing model**
- **Core Network sharing model**
- **Network Roaming sharing model**



Network sharing scenarios
End-to-end QoS architecture for SLA enforcement



- Radio Admission Control
- Traffic shaping per operator
- DL & UL policing per radio bearer and per UE
- DL & UL shaping (classification, buffering, scheduling)
- L3/L2 marking based on QCI of EPS bearer

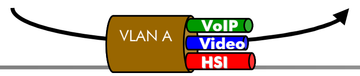
- QoS aware transport

- DL policing per operator
- DL & UL marking

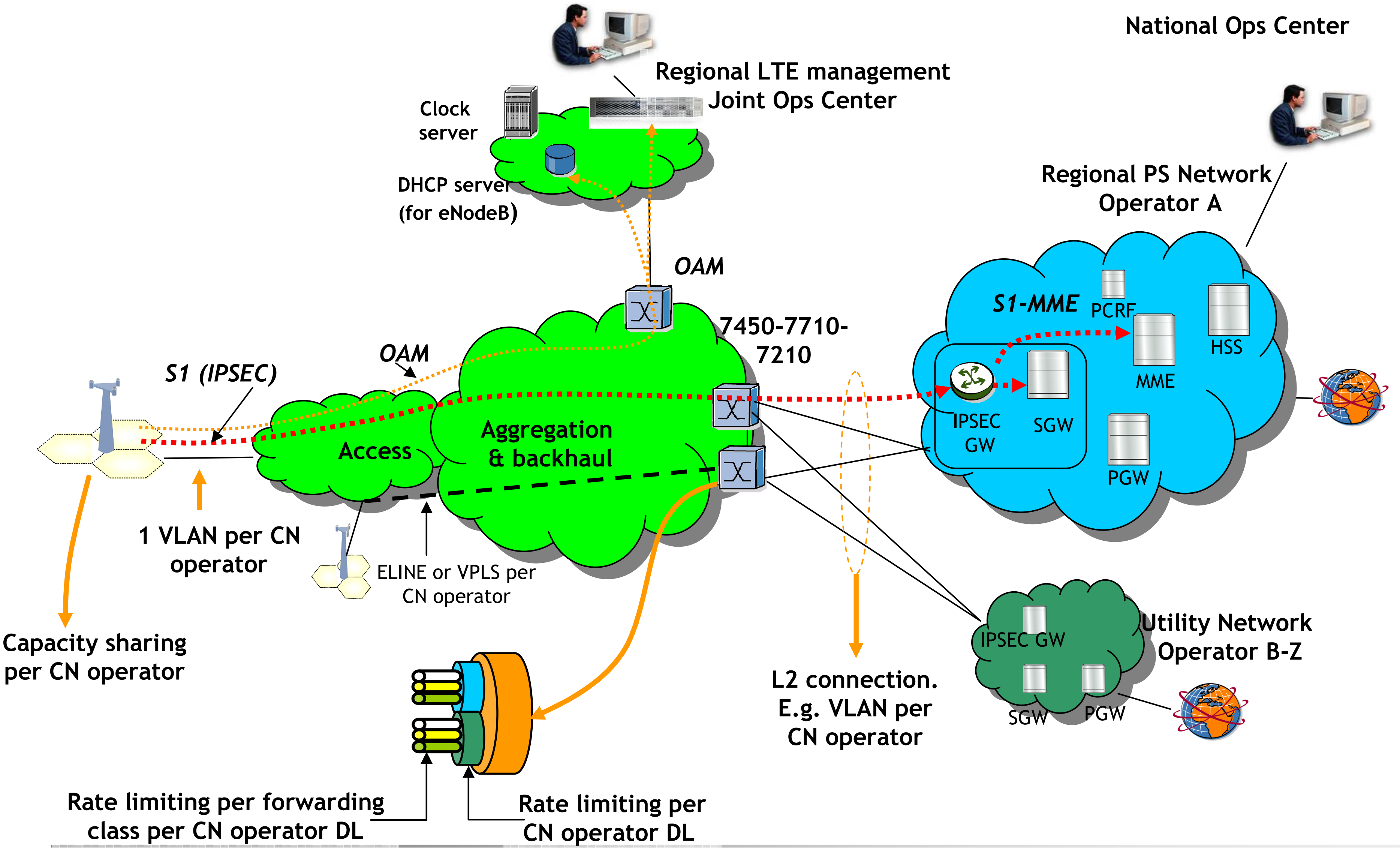
PGW
- DL & UL policing & shaping per service flow
- L3/L2 marking based on QCI of EPS bearer

SGW
-L3/L2 marking based on QCI of EPS bearer

HSS - Home Subscriber Server
PCRF- Policy and Charging Rules Function
MME - Mobility Management Entity



RAN Sharing: End-to-end network architecture example



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Key Take Aways

Hardening and service availability requirements are compatible

Utility service requirement is ubiquitous, not just population-centric

- Massive reduction in cost from shared physical infrastructure
- Utilities have money and incentive to build
- Opportunity for greatly accelerated deployment - think 5 years to nationwide coverage

Expanded market place gives incentive to UE vendors to create ruggedized chips and devices appropriate to the two markets

Secondary Access does not need to mean total pre-emption

- Utility bandwidth requirements are similar -- low bit rate during normal ops, increased during emergency events that usually do not coincide with Public Safety events
- Some utility functions can not be pre-empted without massively adding to the chaos, but they are very low bit rate and manageable with the QoS functions
- Opportunity for increased situational awareness and collaboration of both groups during events

Joint local control and operations centers allow for quicker response, national-level operations simplifies “out-of-area” assistance for both groups

Technically feasible, reasonable, and self-funding www.alcatel-lucent.com