IEEE 802 Tutorial –
Heterogeneous Networking among the IEEE 802 Family:
Proposal for an OMNI Standard

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Re:

IEEE 802.16-12-0393-00-Gdoc (tutorial request form)

Base Contribution:

[none]

Purpose:

To provide the slides for IEEE 802 Tutorial #3 of 2012-07-16 in San Diego, California, USA.

IEEE 802 Tutorial – Heterogeneous Networking among the IEEE 802 Family: Proposal for an OMNI Standard

16 July 2012

San Diego, CA, USA

Harry Bims (Bims Laboratories, Inc.)
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Abstract

Proposals arising in the IEEE 802.16 Study Group on Heterogeneous Networks (HetNet Study Group) have suggested the development of a new IEEE 802 Open Mobile Network Interface (OMNI) standard to specify a common method of heterogeneous networking among all (or at least many) IEEE 802 access technologies for mobile broadband IP services. This tutorial highlights discussions within the Study Group and current plans, particularly in the context of related activities and specifications from other organizations, including IETF and the WiMAX Forum. The intent is to inform IEEE 802 participants about the current thoughts, directions and evolving plans, including considerations about the best home for eventual standardization work, and to encourage additional perspectives.

Status of IEEE 802.16's HetNet Study Group

("Study Group on WirelessMAN radio interface in Heterogeneous Networks")

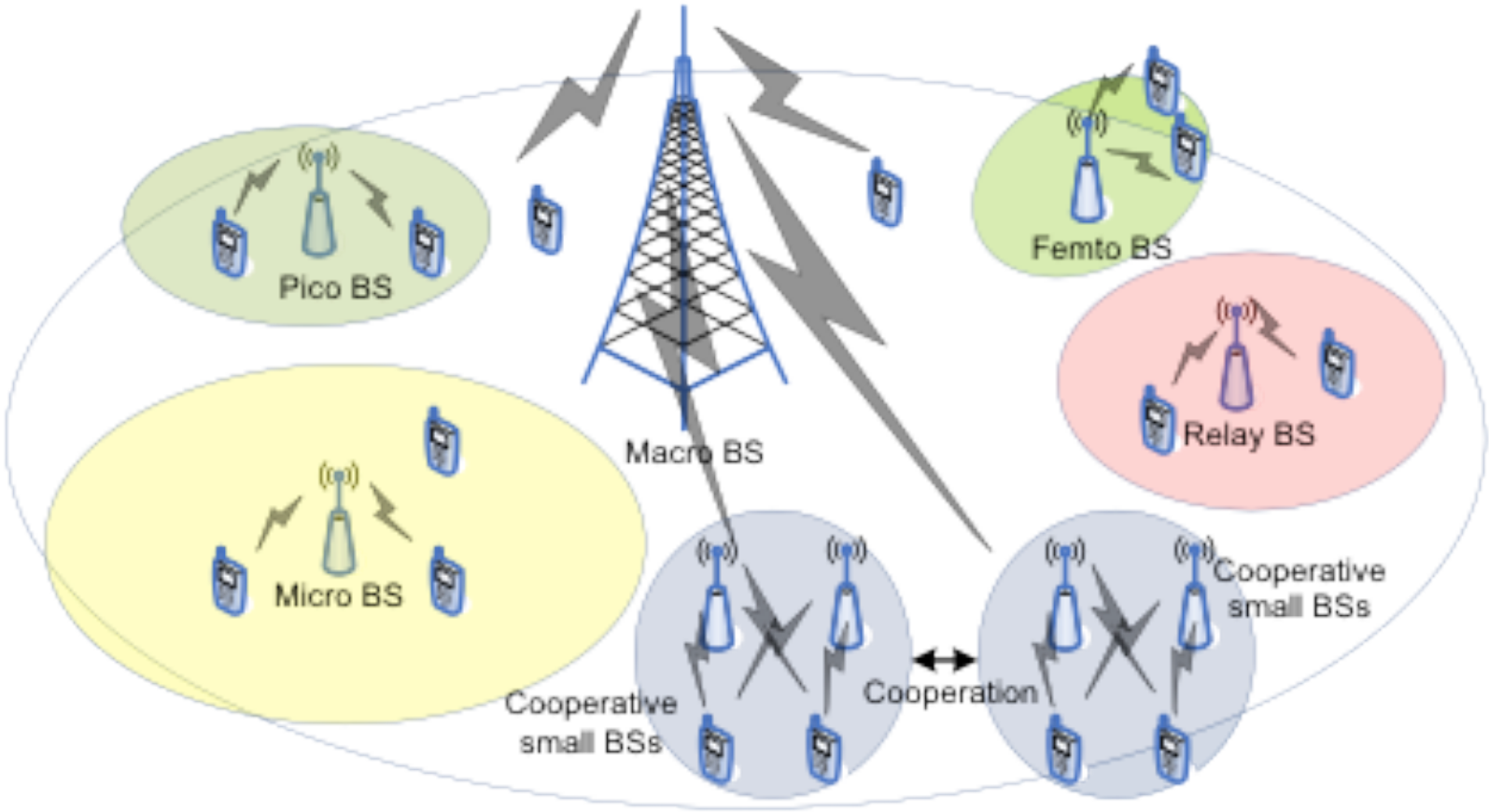
Harry Bims
Bims Laboratories, Inc.

see also:
IEEE 802.16-12-0390-01-Gdoc
IEEE 802.16-12-0351-00-Shet
IEEE 802.16-12-0354-00-Shet
IEEE 802.16-12-0392-00-Shet
IEEE 802.16-12-0397-00-Shet

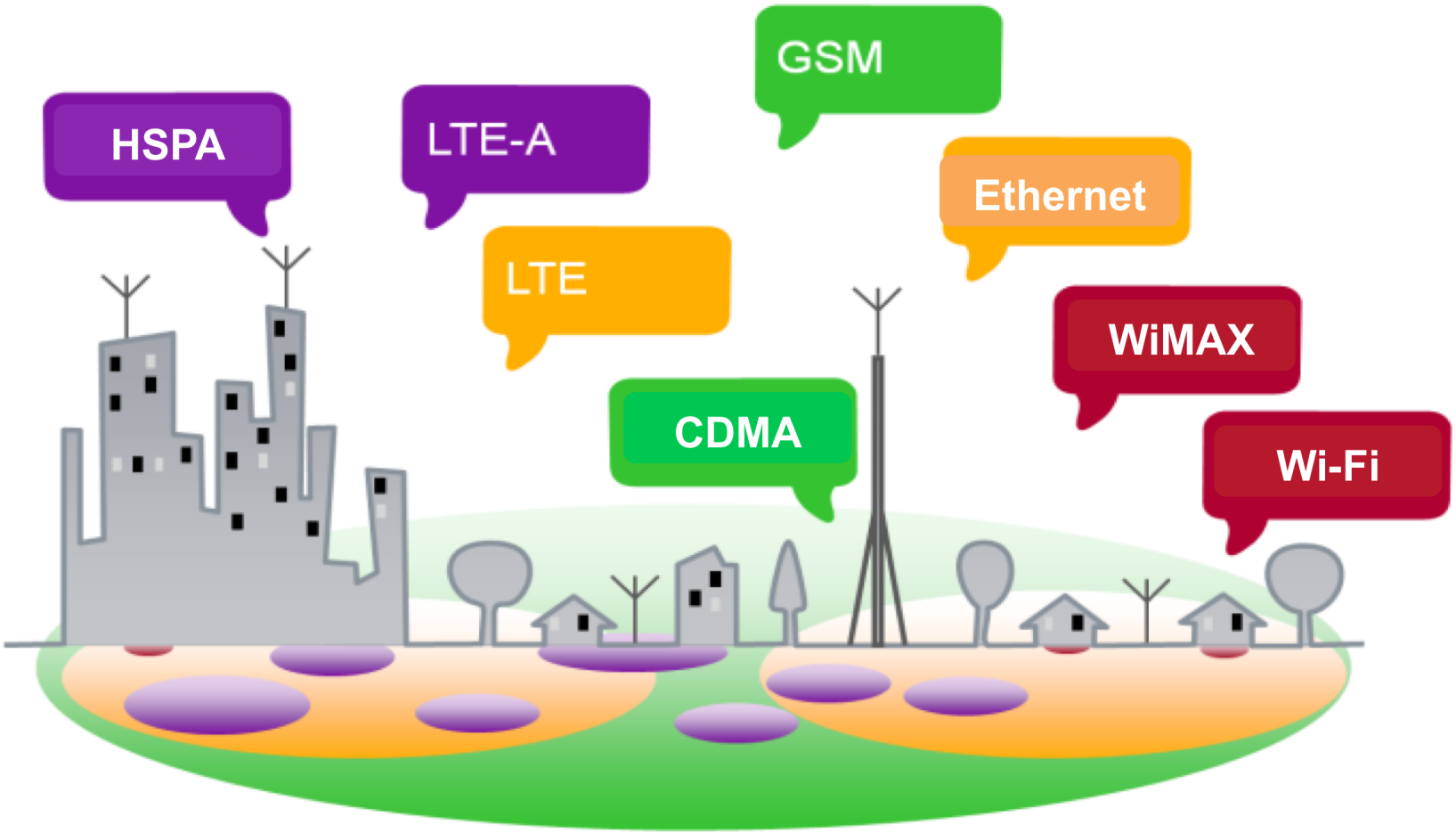
What exactly is a heterogeneous network?

There are at least four possible definitions . . . .

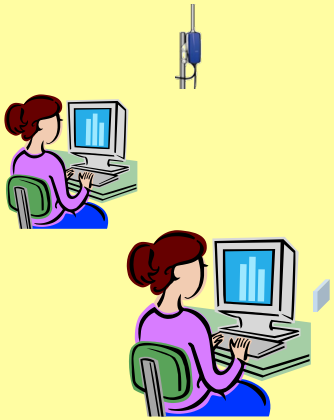
Multi-tier or Multi-Layer Heterogeneous Network (single RAT)



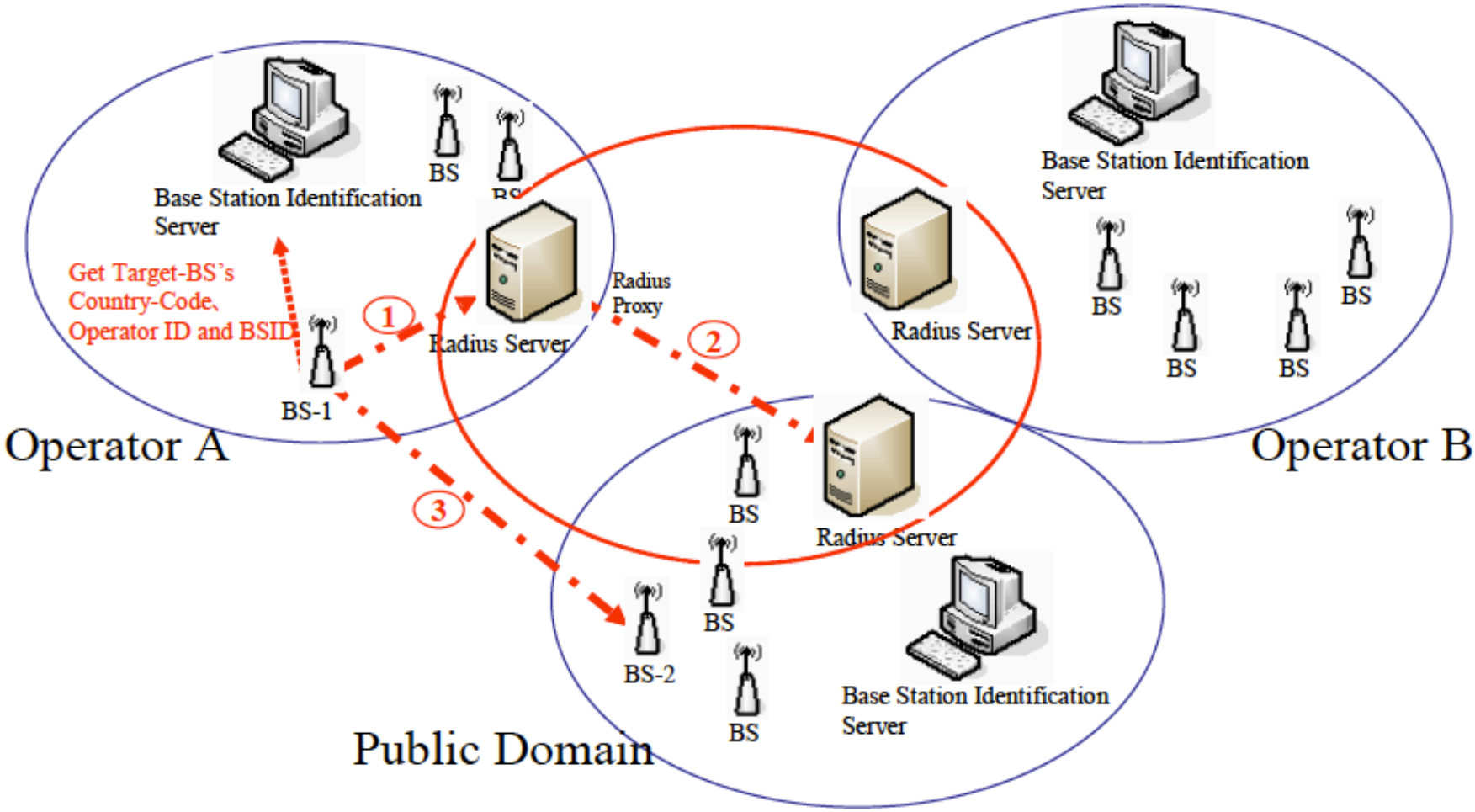
Multi-RAT Heterogeneous Network



Multi-Service Heterogeneous Network

Fixed	Nomadic	Portable	Mobile
DSL, Cable, FWA	Fixed WiMAX Wi-Fi	Wi-Fi	Cellular
			
no session continuity		***session continuity***	***seamless handover***

Multi-Operator Heterogeneous Network



IEEE 802 Scope per IEEE Std 802-2001

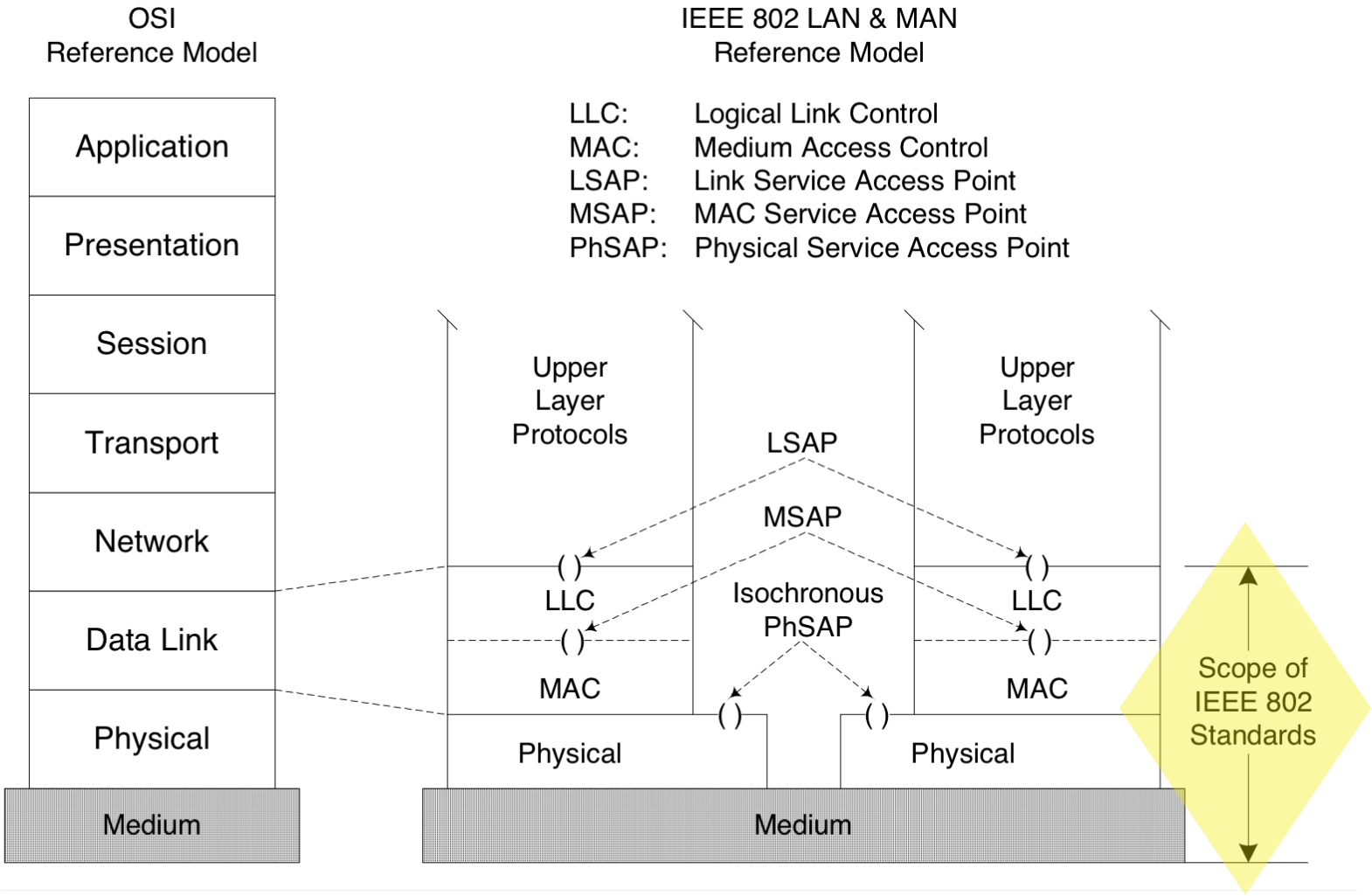


Figure 1—IEEE 802® RM for end stations (LAN&MAN/RM)

IEEE 802 Scope per IEEE P802-REV/D1.4 (June 2012)

MAC medium access control sublayer
MSAP MAC service access point
LSAP link service access point
PSAP PHY service access point

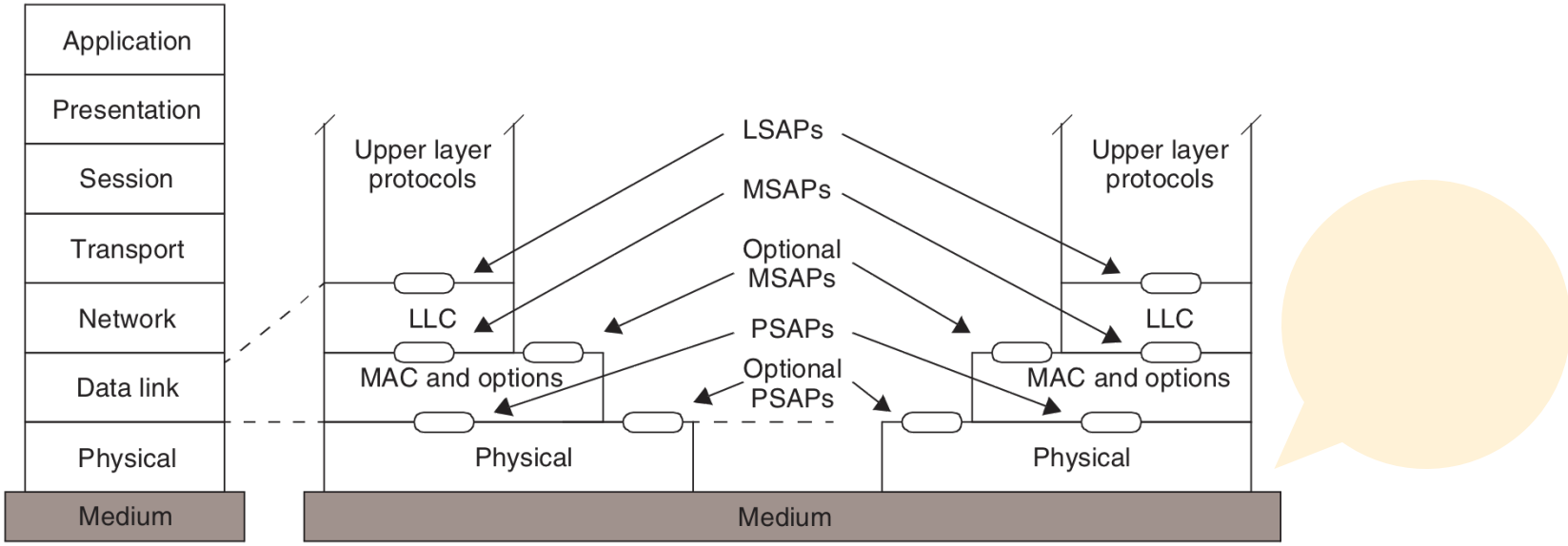


Figure 3—IEEE 802 RM for end stations

But:
(1) “Scope of IEEE 802 standards” (plus related arrows and lines) stricken from P802-REV/D1.4 (June 2012)
(2) “The scope of 802 standards is not limited to only MAC and PHY standards.” (P802-REV/D1.3 and P802-REV/D1.4)

HetNet Study Group Proposals

- PAR proposals have been received for:
  - Multi-Tier: amendment to IEEE Std 802.16
  - Multi-RAT: Open Mobile Network Interface (OMNI)
    - Organizationally, belongs above 802.16
    - Architecturally, belongs above Layer 2

Estimated OMNI Project Timeline

DATE	Activity
March 16	IEEE 802 initiated HetNet Study Group (SG)
May 14 - 17	First HetNet Study Group session
July 16	IEEE 802 OMNI Tutorial
July 16 - 19	Second HetNet Study Group session Likely request to renew SG
September 17 - 21	Third HetNet Study Group session Prepare OMNI PAR for submission
November 12 -16	IEEE 802 can approve OMNI PAR
December 5	IEEE-SA can initiate OMNI PAR

WiMAX Network Architecture Concepts for Heterogeneous Networking in IEEE802

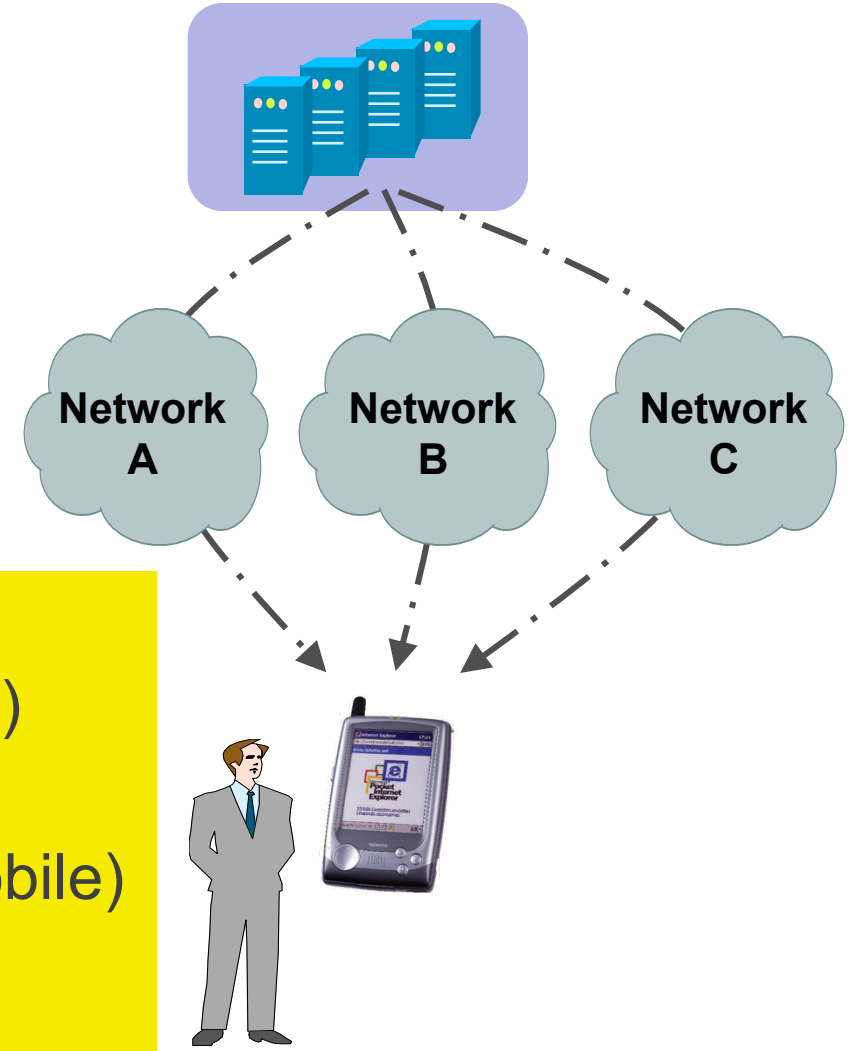
Max Riegel
Nokia Siemens Networks

see also:
IEEE 802.16-12-0354-00-Shet
IEEE 802.16-12-0355-00-Shet

Heterogeneous Networking

"Getting access to the same content or applications by different networks."

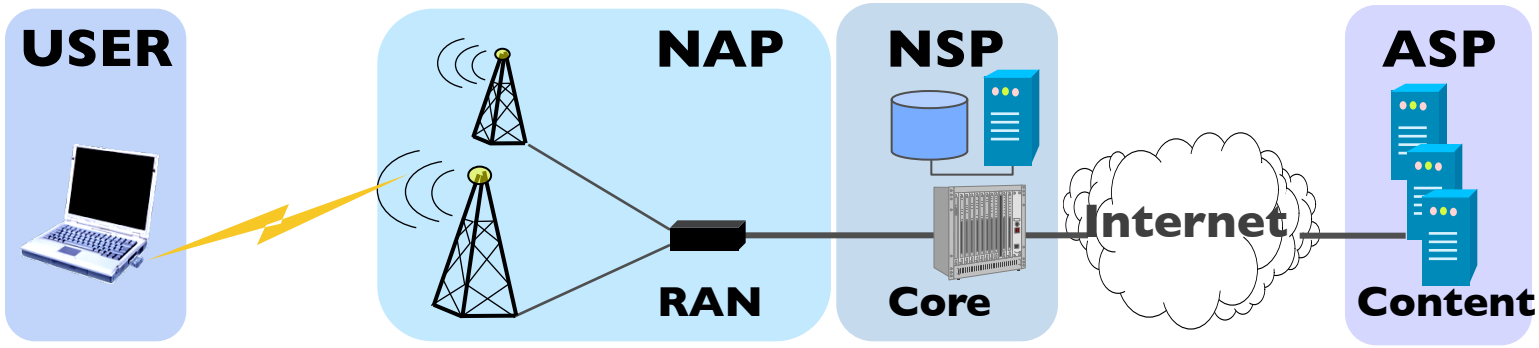
- Can span:
  - "Multi-Tier" or "Multi-Layer" (various cell sizes)
  - "Multi-RAT" (various access technologies)
  - "Multi-Service" (fixed, nomadic, portable, mobile)
  - "Multi-Operator"



Why Heterogeneous Networking?

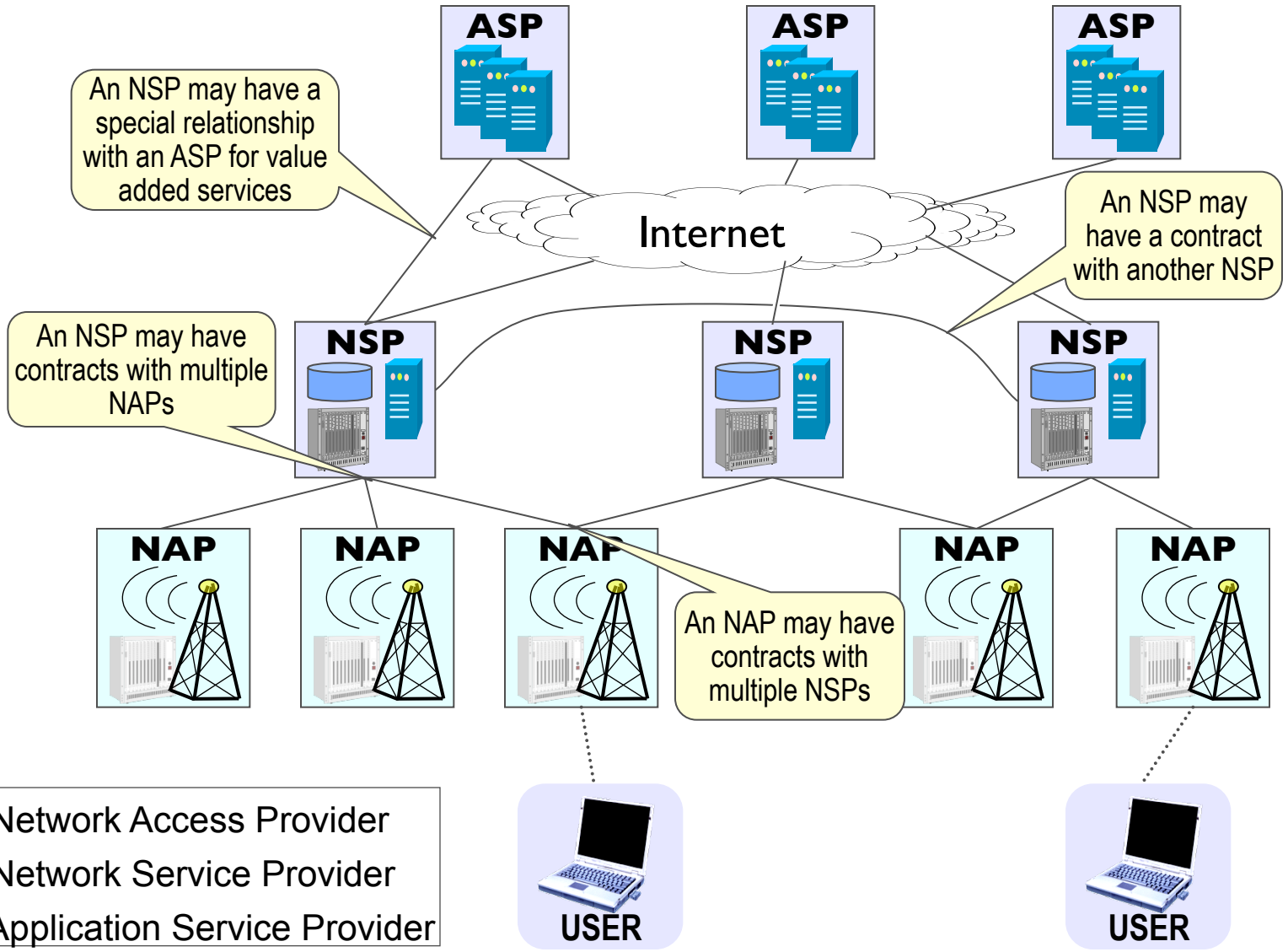
- Heterogeneous Networking is deployed for cost and performance reasons
  - Multi-Layer/Multi-Tier
    - Radio access network adaptation to the capacity needs
  - Multi-RAT
    - Better performance and efficiency by specialized radios
  - Multi-Service
    - Minimizing network complexity according to demand
  - Multi-Operator
    - Better network economics by shared use
- Heterogeneous Networking is considered as the solution for the data explosion in the networks.

Network Partitioning
for the Internet



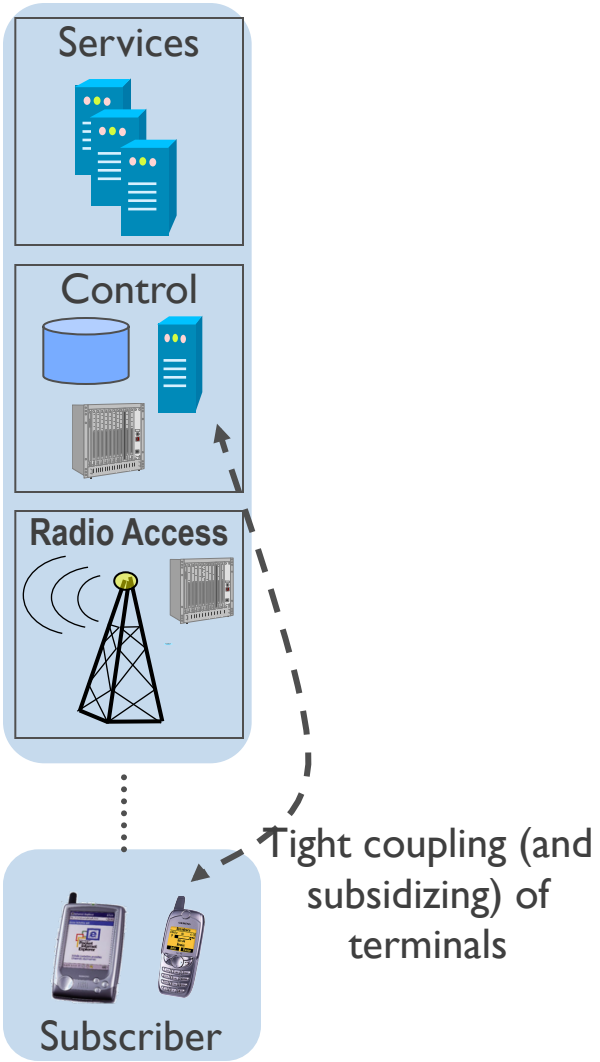
- The Internet decouples the content and services from the access infrastructure
- The access infrastructure itself is usually divided into a service control part (Core) and a service delivery part (RAN = Radio Access Network)
- Independent operation of the different network parts is quite common for the Internet.

Multi- RAT/Service/Operator Networking



For Comparison:

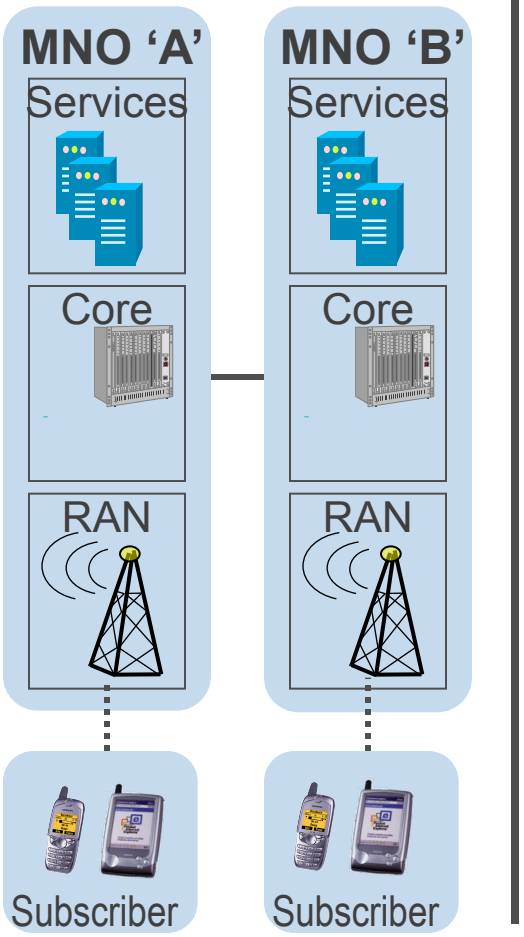
The legacy Mobile Network Structure



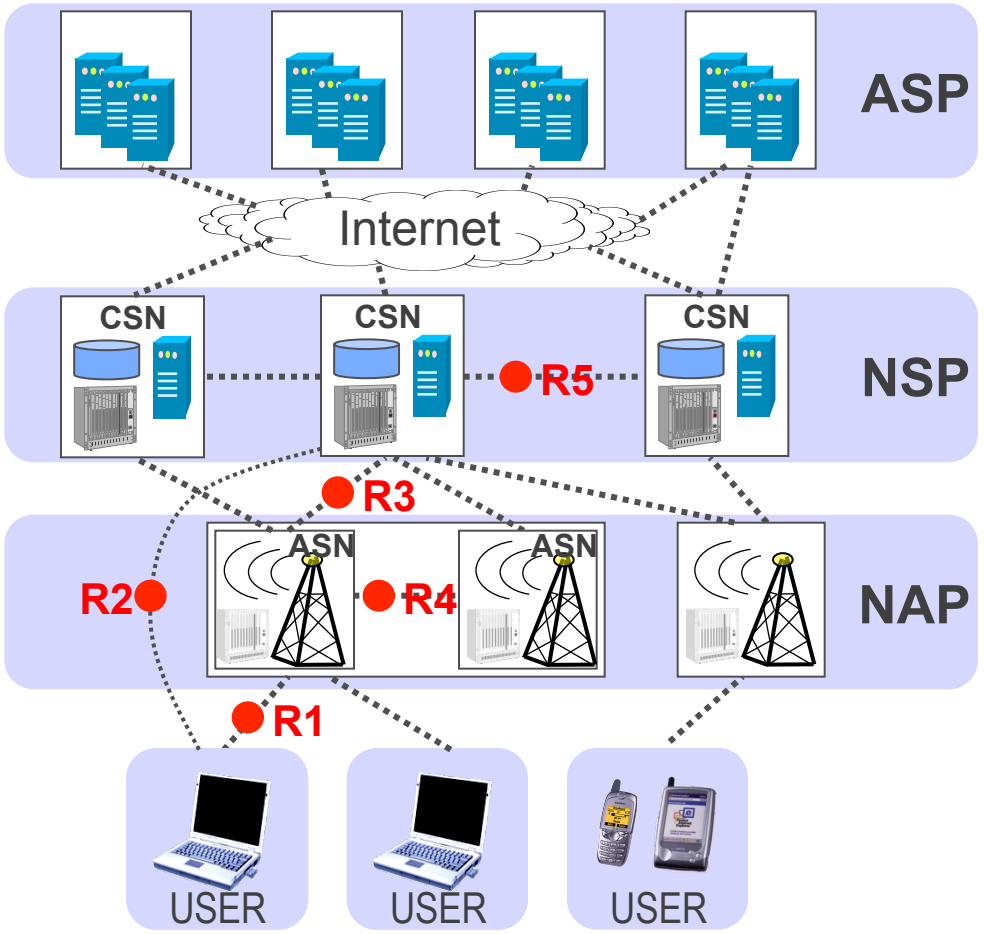
- Same partitioning exists also in legacy telecommunication networks
- However:
  - Services are combined with control and radio access into a single operational entity
  - Terminals are tightly coupled to the operator to ensure proper use, i.e. prevent bypassing the operator's policies and services
  - Value is generated by the services
  - Radio Access and Control are adjusted to the operator's services
  - Complete standardization of services to enable interoperability and roaming

Mobile Network Architectures

Legacy Architecture



Mobile WiMAX Network Architecture

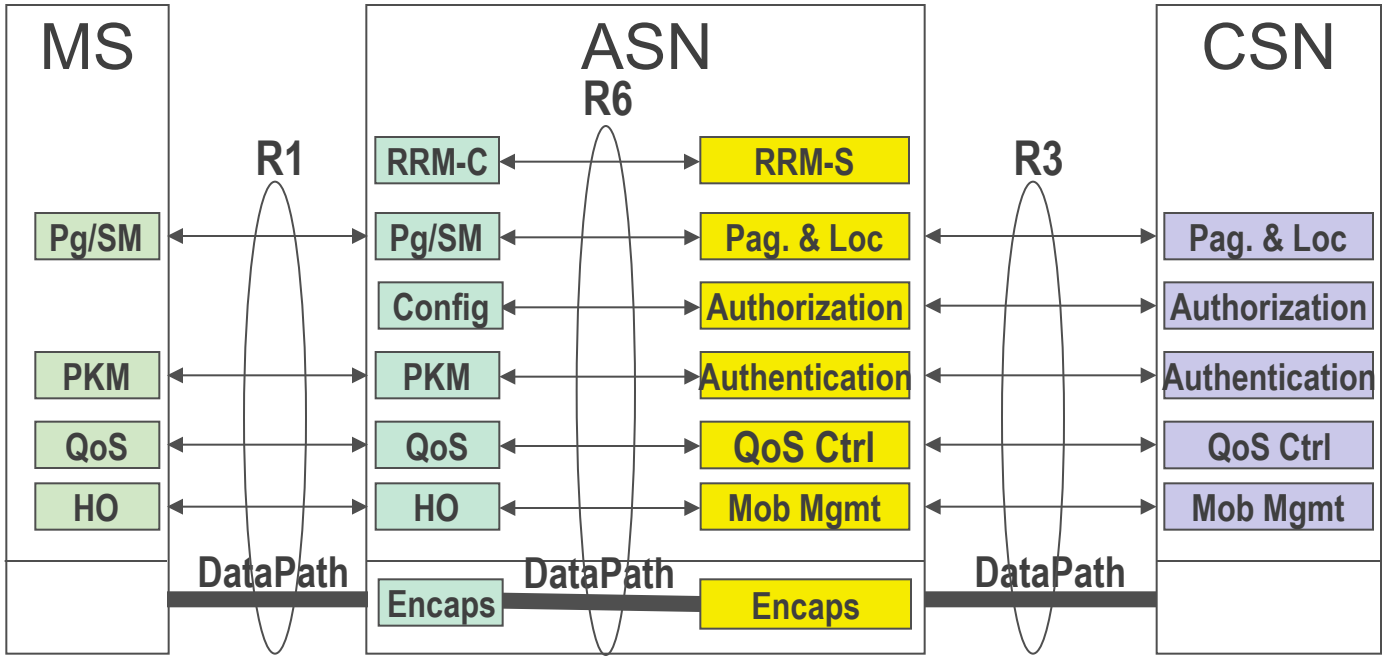


WiMAX Forum created the Mobile Network Architecture for the Internet

WiMAX Network Entities

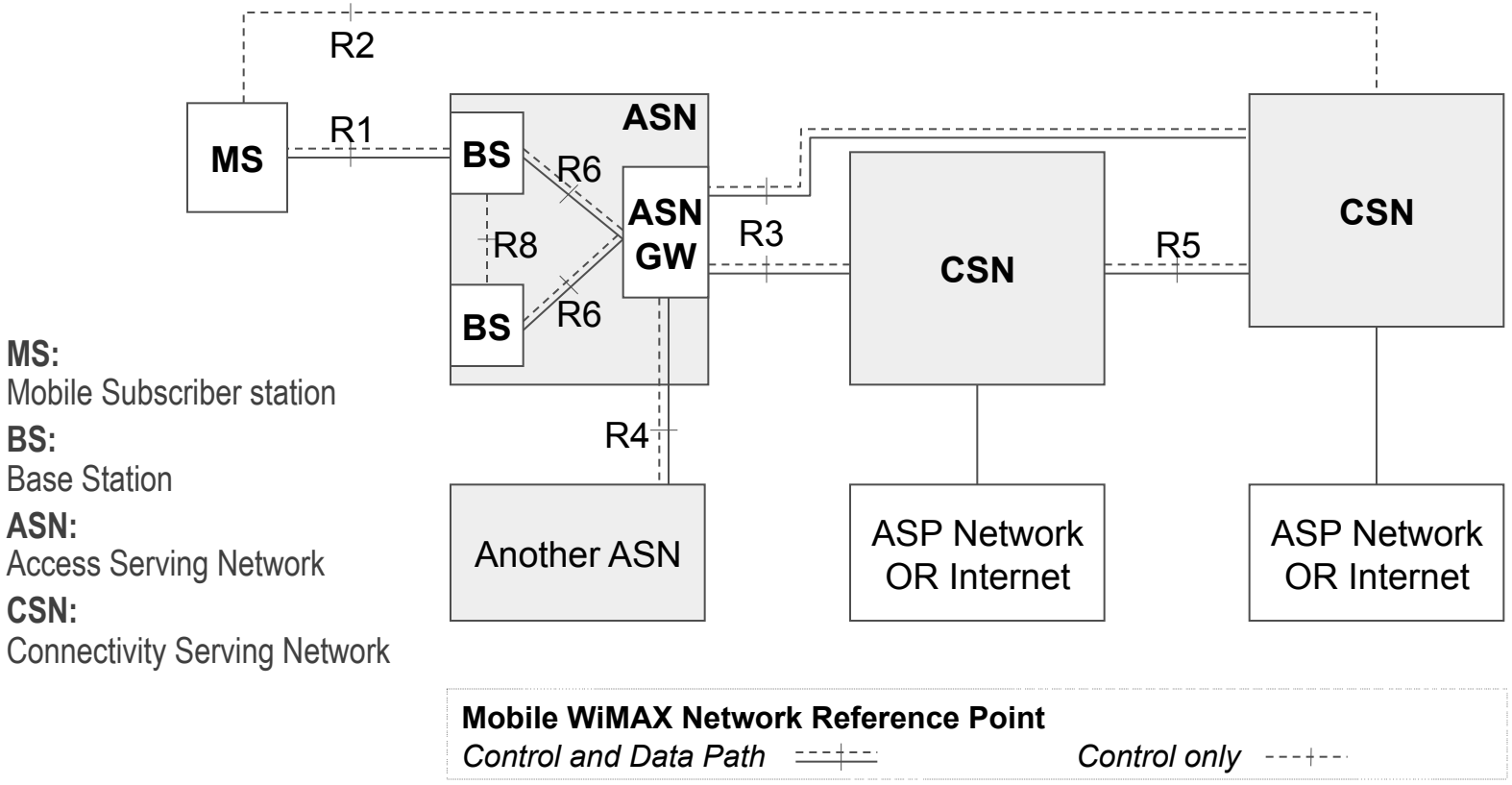
- CSN: Connectivity Serving Network
  Logical representation of the functions of a NSP, e.g.
  - Connectivity to the Internet and direct to ASPs
  - Authentication, authorization and accounting
  - IP address management
  - Mobility and roaming between ASNs
  - Policy & QoS management based on a SLA
- ASN: Access Serving Network
  Logical representation of the functions of a NAP, e.g.
  - 802.16 interface w/ network entry and handover
  - Radio Resource Management & admission control
  - L2 Session/mobility management
  - QoS and policy enforcement
  - Mobile Access Gateway (MAG)
  - Forwarding to selected CSN

WiMAX Reference Points



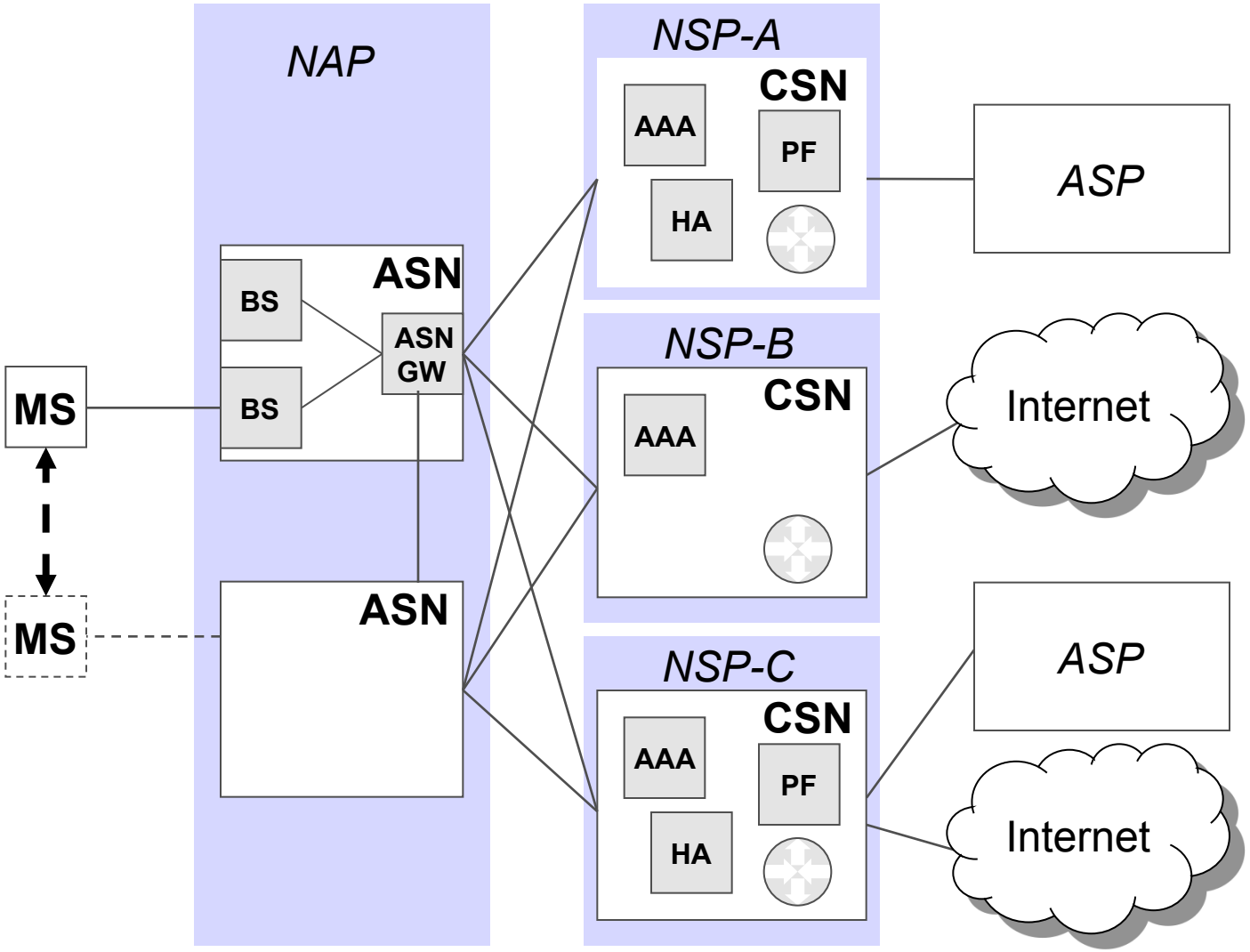
- NRM Reference Points represent a bundle of protocols
  - Similar to a real IP network interface
- The implementation of a particular protocols over a reference point is optional
  - If a particular protocol is present, it must conform to the WiMAX specification

Mobile WiMAX Network Reference Model



Different interoperable implementations of ASN and CSN possible. One single model of functional split of ASN into BS and ASN-GW standardized.

‘Heterogeneous’ Deployment of the Mobile WiMAX Architecture



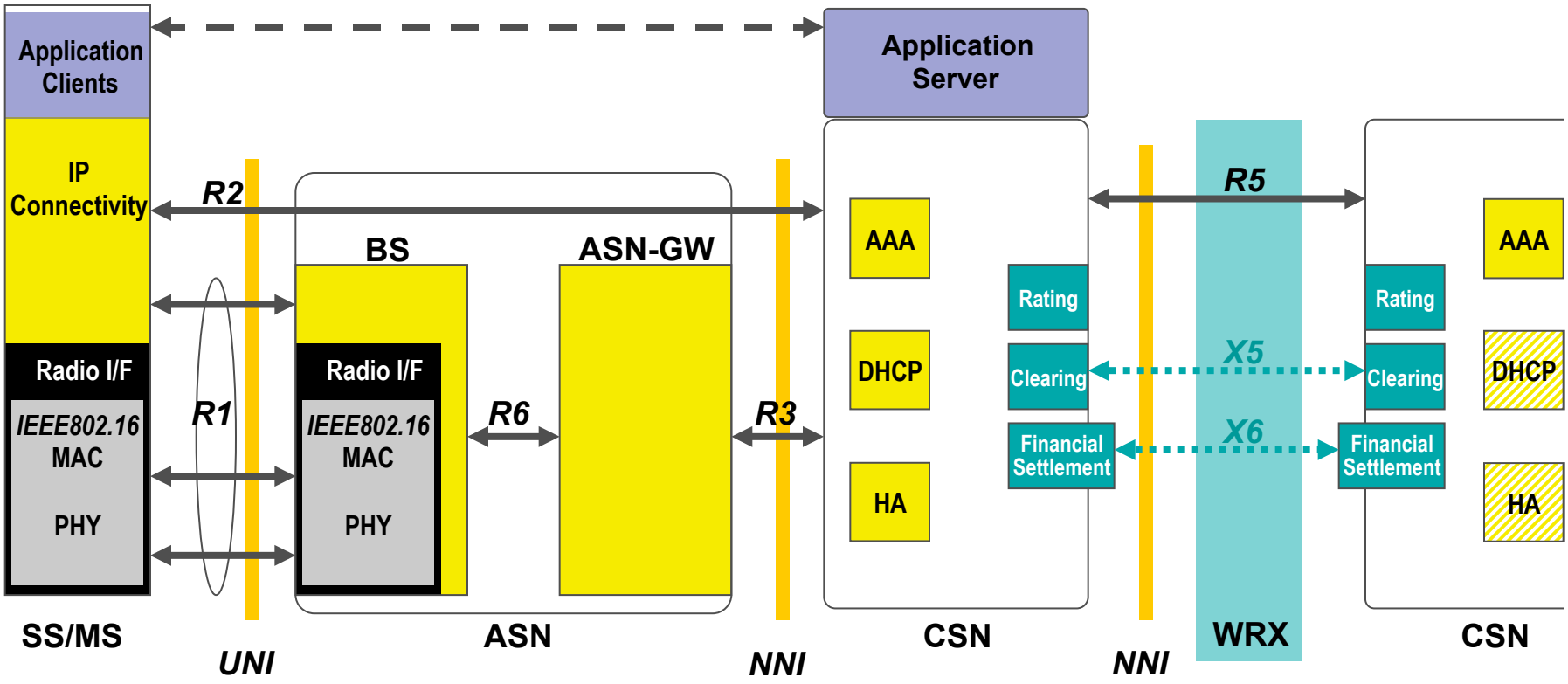
WiMAX Networking Summarized

- Interoperability enforced via reference points without dictating how vendors implement edges of reference points
- Introduces the notion of functional entities – which can be combined or decomposed by vendor and/or operator
- No single physical ASN or CSN topology is mandated – allowing room for vendor / operator differentiation
  - Standardized decomposition of ASN into BS and ASN-GW
  - CSN is fully kept opaque; no aim for standardized implementations
- Mobility is mainly achieved by ASN anchored MM (R6, R4)
  - R3 mobility (MIP) is used for path optimization, network sharing and wide-area nomadicity, but not for seamless handover.
- AAA and Roaming is based on IETF EAP supporting any kind of ‘credentials’ (Password, Certificate, SIM & U-SIM)

Heterogeneous Networking in IEEE 802

- IEEE 802 provides a variety of optimized PHYs and MACs for
  - fixed, nomadic, portable and mobile service
  - macro, micro, pico and femto cells + ‘wired’
- However, IEEE 802 does not provide any specifications for inter-operator relations or higher layers of the Network-User-Interface.
- Due to the variety of its User-Network Interfaces, heterogeneous networking seems to be a valuable topic for IEEE 802.

Mobile WiMAX Specification Framework



- WiMAX provides ‘generic’ network specifications for:
  - User Network Interface (Authentication, IP-Configuration, Provisioning) on top of IEEE 802.16 radio specification
  - Network Network Interface (Network sharing, Roaming)

Leveraging WiMAX Specifications for heterogeneous networking in IEEE 802

- While somewhat specific to IEEE 802.16, WiMAX network specifications can be leveraged to define generic network interfaces across all IEEE 802 technologies
  - User authentication and device provisioning
  - QoS and policy control
  - Network sharing and Roaming
  - (Mobility, when needed!)

References for Mobile WiMAX Networking

- WiMAX Forum Specifications
  - WMF-T32-001-R020v01 - WiMAX Forum® Network Architecture - Architecture Tenets, Reference Model and Reference Points Base Specification - Release 2
    - http://www.wimaxforum.org/sites/wimaxforum.org/files/technical_document/2012/04/WMF-T32-001-R020v01_Network-Stage2-Base.pdf
  - WMF-T33-001-R020v01 - WiMAX Forum® Network Architecture - Detailed Protocols and Procedures, Base Specification - Release 2
    - http://www.wimaxforum.org/sites/wimaxforum.org/files/technical_document/2012/04/WMF-T33-001-R020v01_Network-Stage3-Base.pdf
- Text Books with particular focus on WiMAX networking aspects
  - WiMAX Technology and Network Evolution
    - Kamran Etemad, Ming-Yee Lai
  - Deploying Mobile WiMAX
    - Max Riegel, Aik Chindapol, Dirk Kroeselberg

An IEEE 802 OmniRAN

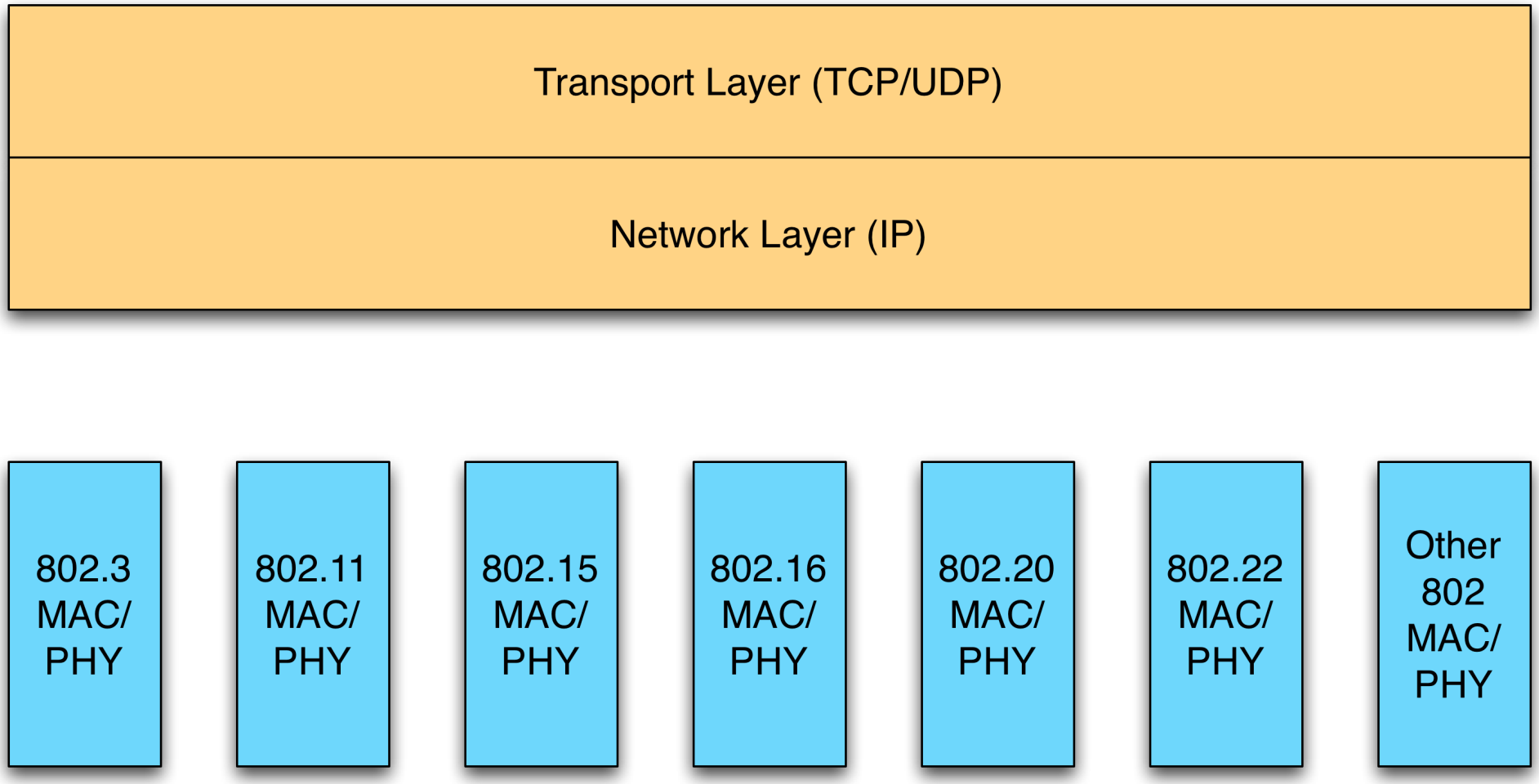
Roger Marks
Consensii LLC & WiMAX Forum

see also:
IEEE 802.16-12-0350-00-Shet
IEEE 802.16-12-0351-01-Shet
IEEE 802.16-12-0352-01-Shet
IEEE 802.16-12-0449-00-Shet
IEEE 802.16-12-0450-00-Shet

“OmniRAN” Terminology

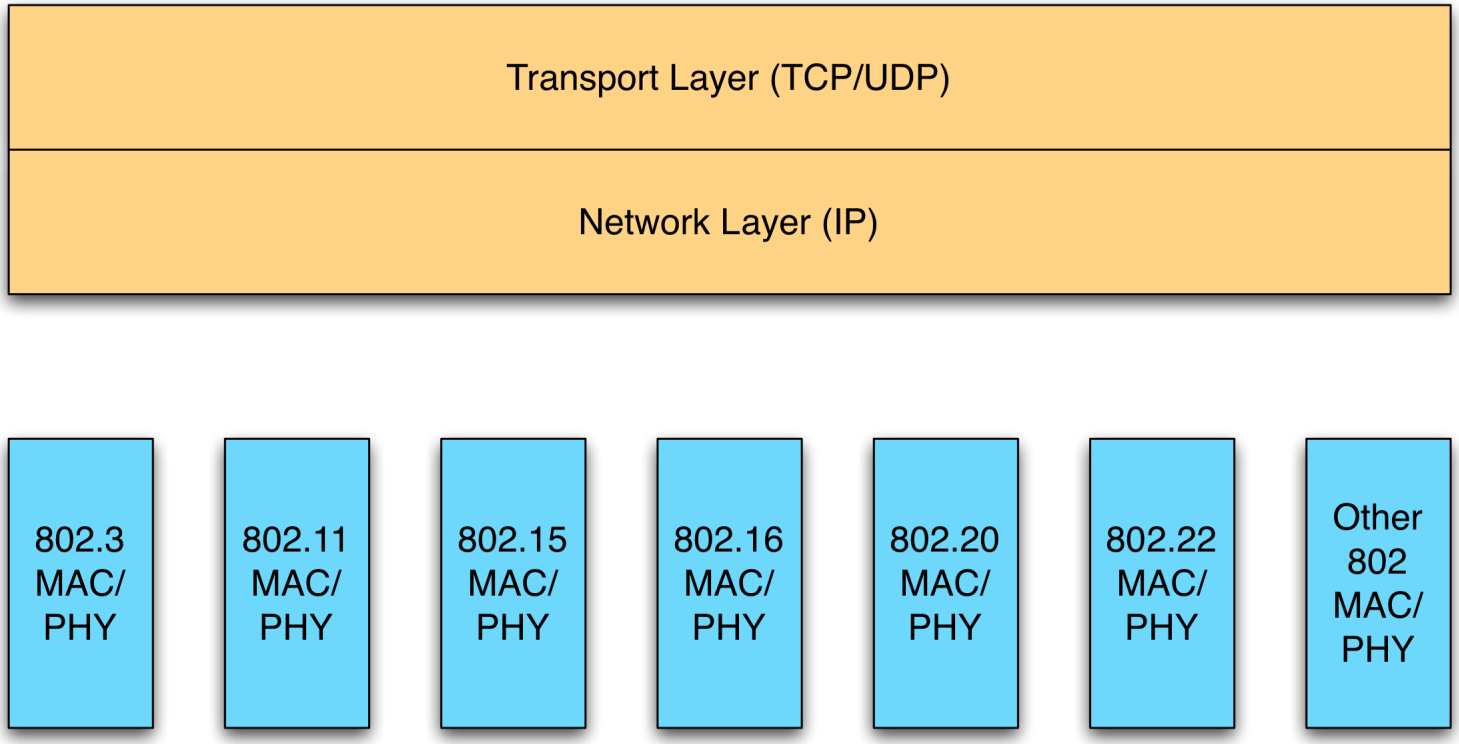
- RAN: “Radio Access Network” (widely used term)
- OMNI: “Open Mobile Network Interface”
  - Supports multiple RANs
  - “Mobile” can include fixed and nomadic elements
- IEEE “Area Networks”, such as:
  - LAN: Local Area Network
  - MAN: Metropolitan Area Network
  - PAN: Personal Area Network
  - etc.
- OmniRAN:
  - “Omni-Range Area Network”, based on OMNI

The Internet over IEEE 802



What's wrong with this picture?

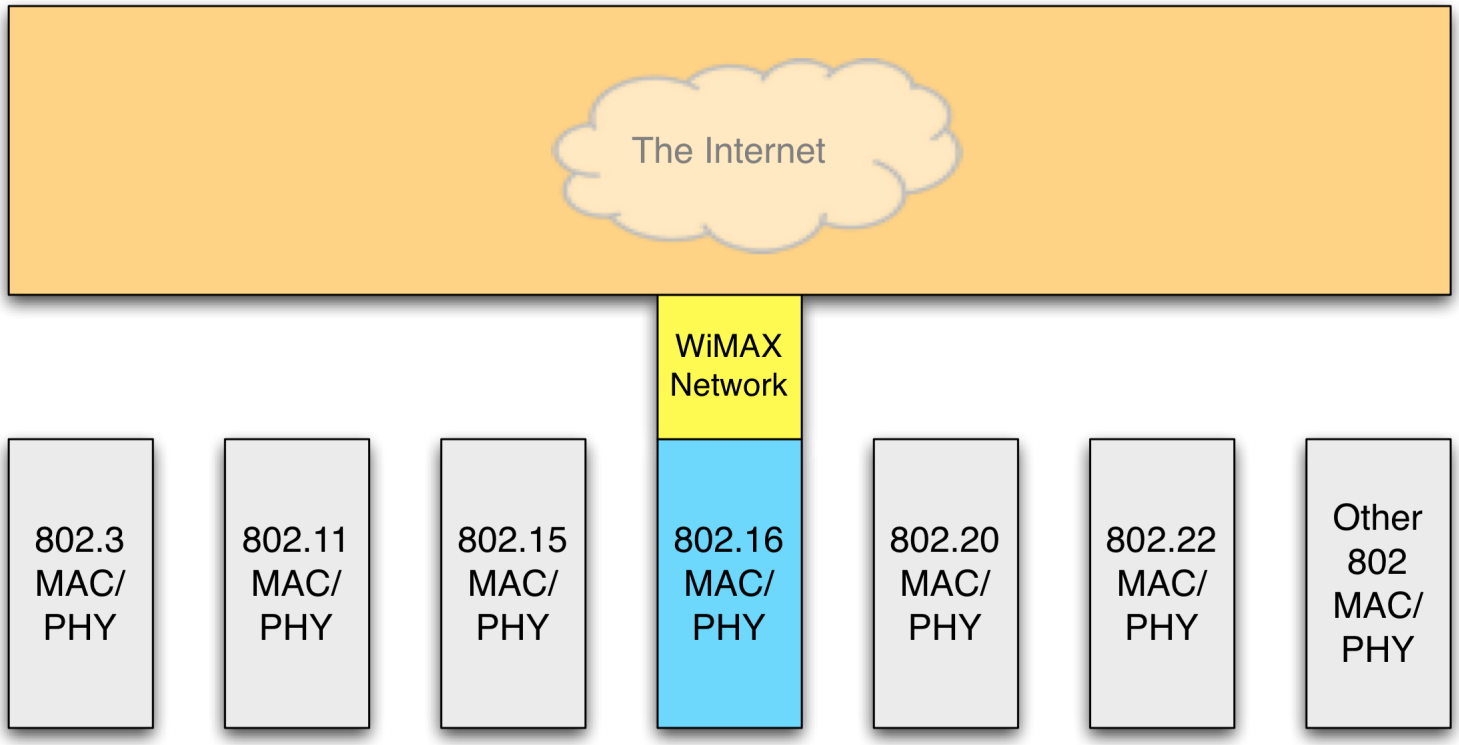
Mind the Gap



(1) Is this a family of standards? Or just roommates?

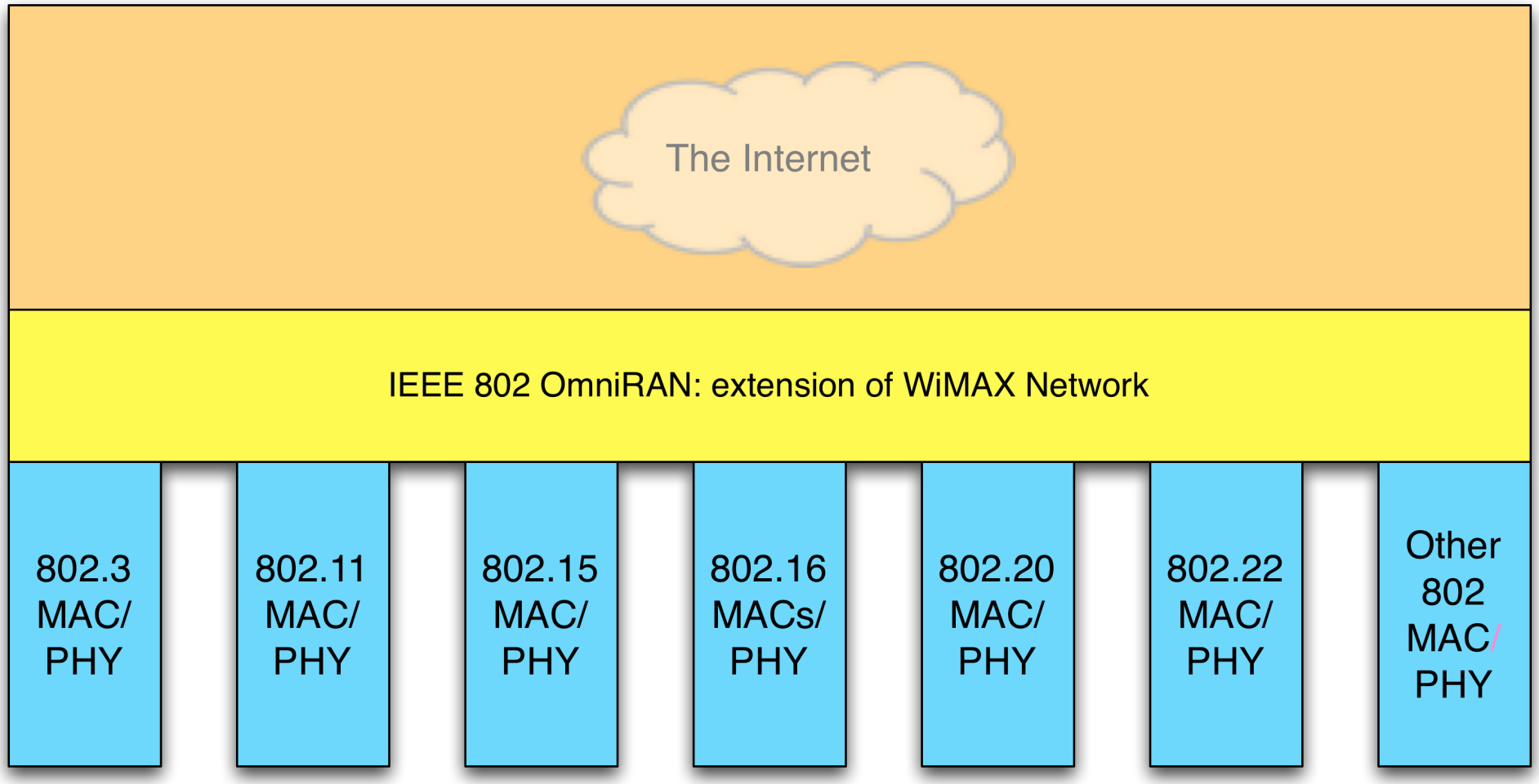
(2) Where are the functionalities needed in a commercial mobile network?

IEEE 802.16 in Commercial Service



WiMAX Network provides operator-required services to 802.16 devices: authentication, provisioning, mobility management, QoS management, roaming...

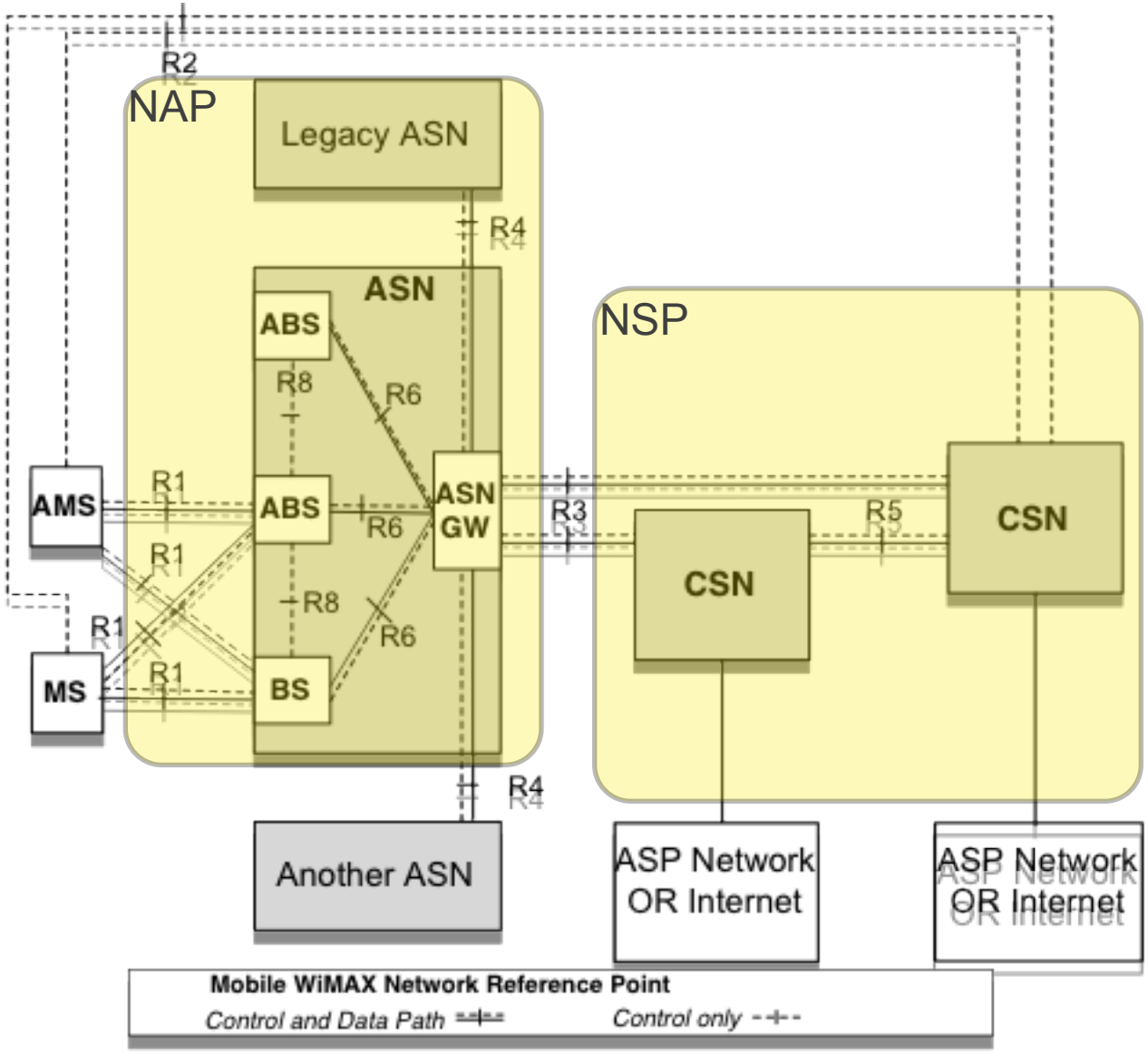
Closing the Gap: OmniRAN as a HetNet



OmniRAN Functionality Menu

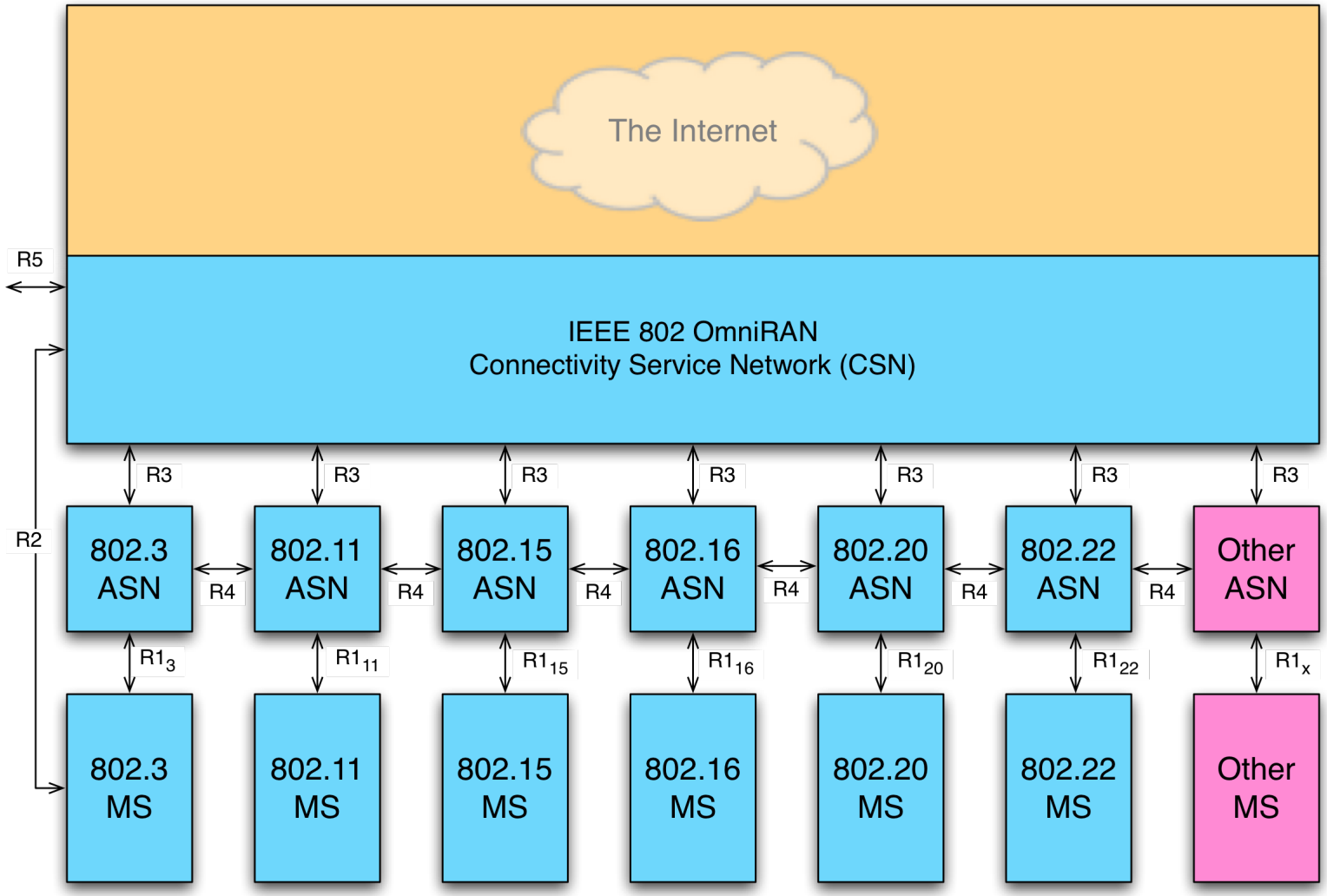
- Network Discovery and Selection
- Authentication & Security
- Provisioning
- Accounting, Charging, and Settlement
- Connection Management
- QoS, Admission Control and Service Flow
- Power Management
- Interworking and Roaming
- Radio Resource Management
- Operation, Administration, Maintenance and Provisioning
- Lawful Interception
- Location Services
- Emergency Telecommunications Service
- VoIP

WiMAX Forum Network Architecture



MS, AMS	Mobile Station
BS, ABS	Base Station
ASN	Access Service Network
CSN	Connectivity Service Network
ASP	Application Service Provider
GW	Gateway
NAP	Network Access Provider
NSP	Network Service Provider

OmniRAN Architecture



Target Market for OmniRAN

- Operators (including WiMAX Operators; wireless ISPs; current wireline & utility operators; etc.) with focus on:
  - IP connectivity
  - a lean, low-complexity network
  - mobility functions, such as authentication, provisioning, handover, billing and roaming (even in fixed deployments)
  - possible heterogeneous deployments
    - could support homogeneous as well

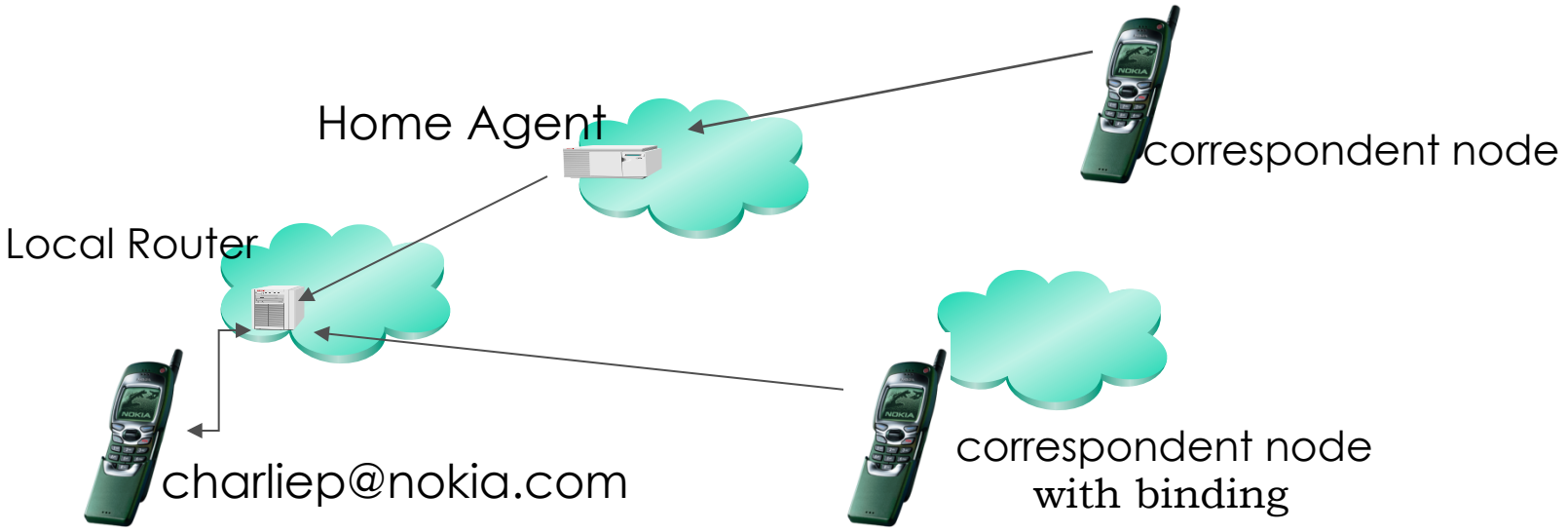
Segment Conclusions

- IEEE 802 OmniRAN can close the gap and tie 802 devices into an family of standards within a heterogeneous IP network.
- WiMAX Forum network specifications have been developed and optimized for the required functionality.
- OmniRAN network architecture and functionality can be based on the WiMAX Forum network specifications.
  - Core functionality of the OmniRAN would be as a Connectivity Service Network (CSN).
  - Unified network interfaces to ASN
  - ASNs customized for each interface technology.
- Speaker's recommendation: Standardization will be most efficient in a new 802 Working Group.

IETF Baseline Mobility and Architectures

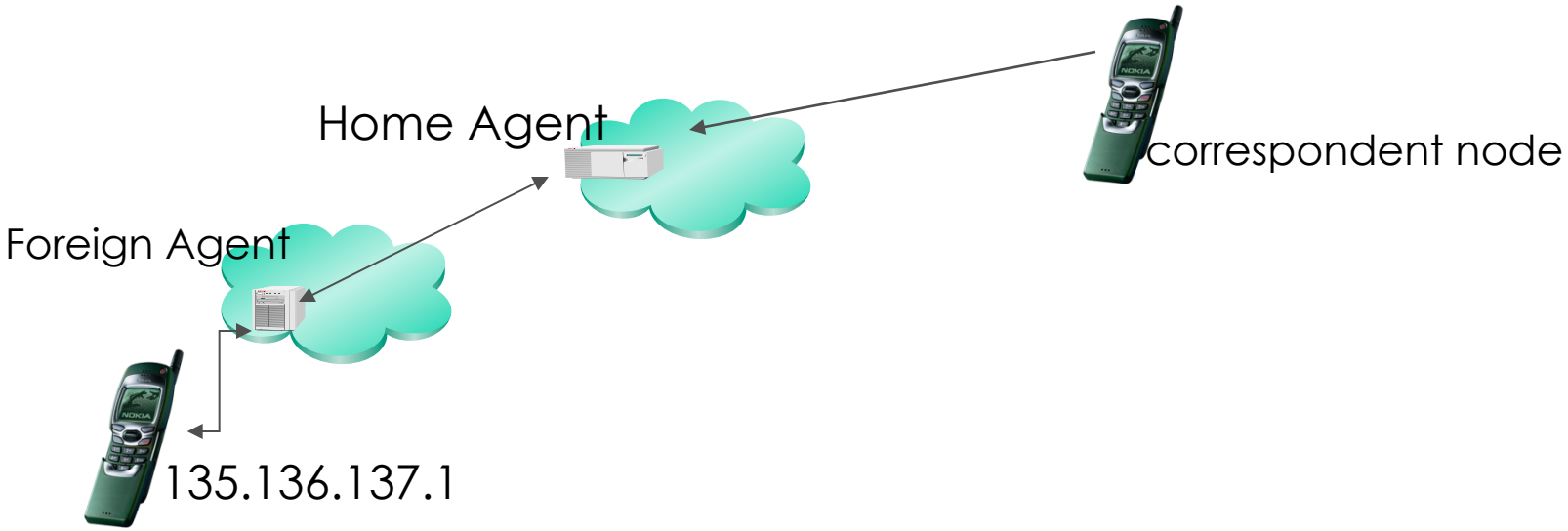
Charlie Perkins
Futurewei

Mobile IPv6 protocol overview



- *Seamless Roaming*: Mobile Node appears "*always on*" home network
- Routing Prefix from local Router Advertisement
- Address autoconfiguration → care-of address
- Binding Updates → home agent & correspondent nodes
  - (home address, care-of address, binding lifetime)

Mobile IPv4 protocol overview



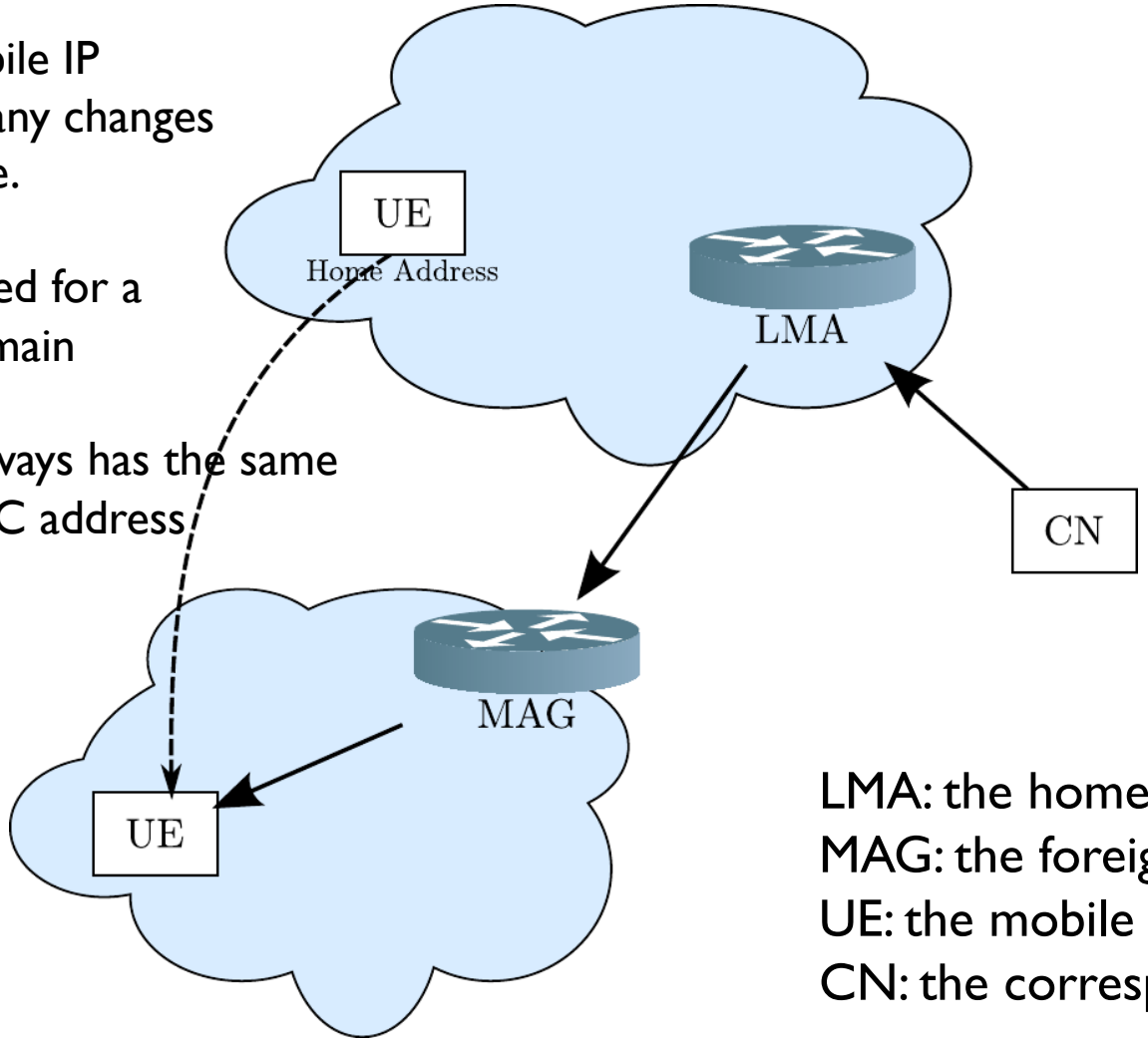
- *Seamless Roaming*: Mobile Node appears "*always on*" home network
- Foreign Agent supplies Care-of Address in Agent Advertisement
- Or, MN address allocation → care-of address
- Registration Request → home agent
  - (home address, care-of address, registration lifetime)

Proxy Mobile IP (PMIP: RFC 5213)

Main idea: run Mobile IP without requiring any changes to the mobile node.

Originally envisioned for a single network domain

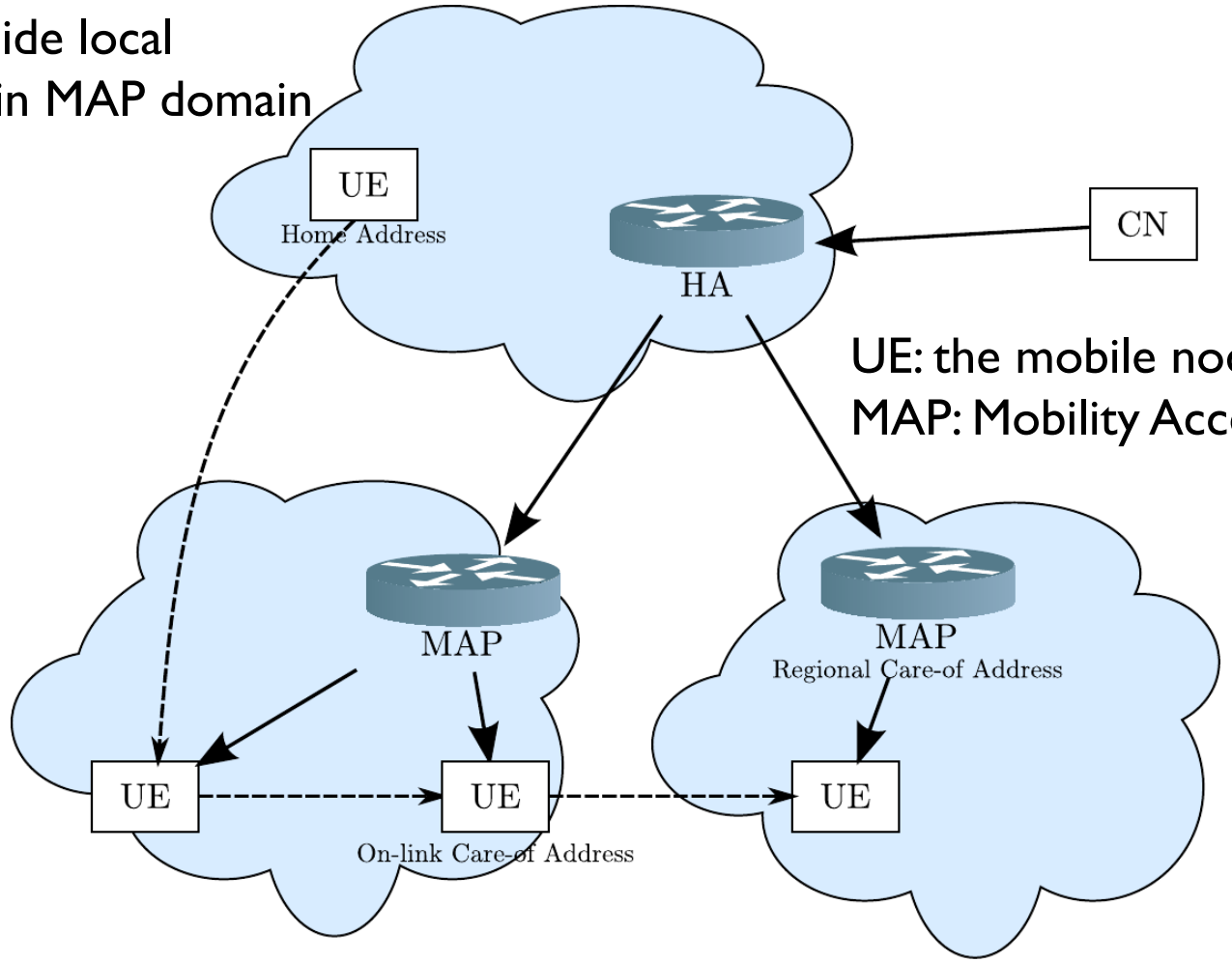
UE thinks MAG always has the same CoA and even MAC address



LMA: the home agent
MAG: the foreign agent
UE: the mobile node
CN: the correspondent node

Hierarchical Mobile IP (HMIP: RFC 5380)

Main idea: hide local movement in MAP domain



UE: the mobile node
MAP: Mobility Access Point

FMIP (RFC 5568): Smooth/Fast/Seamless Handover

- Smooth handover == low loss
- Fast handover == low delay [30 ms?]
  - Can router pre-empt Duplicate Address Detection??
- Seamless handover:
  - *Fast* [localized context transfer via HI and HAck]
  - *Smooth* [buffering]

FMC terminology

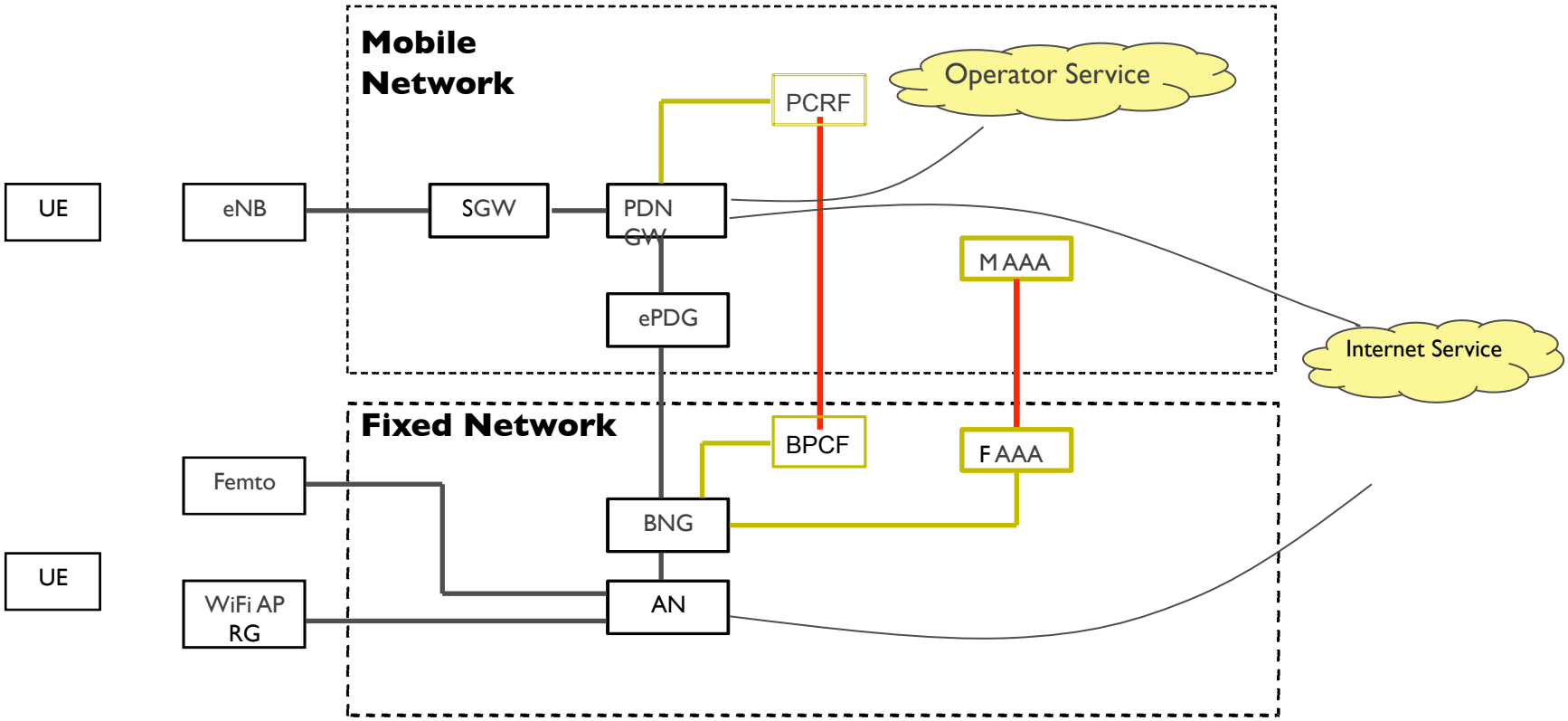
- “Fixed”
  - Fixed means that the access network is DSL
  - Or, maybe femtocell
  - Device is not really “fixed” at all!
- “Mobile”
  - A UE (a device managed by a 3GPP network operator)
- “Convergence”
  - Extend 3GPP policy requirements to WLAN e.g.
- Fixed Mobile Convergence
  - Mostly, bringing BBF into 3GPP compliance
  - But, described as a way of extending user experience
  - But, all the changes are on the BBF side

Why FMC?

1. Mobile applications demand more and more bandwidth;
2. Cellular network becoming the bottle-neck
3. Cellular network operators want to offload the data traffic to the fixed broadband (FBB) network via WLAN/ Home (e)NodeB access;
4. Operators must employ mechanisms to manage the subscriber's service over both mobile and FBB network, that is FMC.

FMC based on subscribers' and operators' requirements.

Architecture of FMC

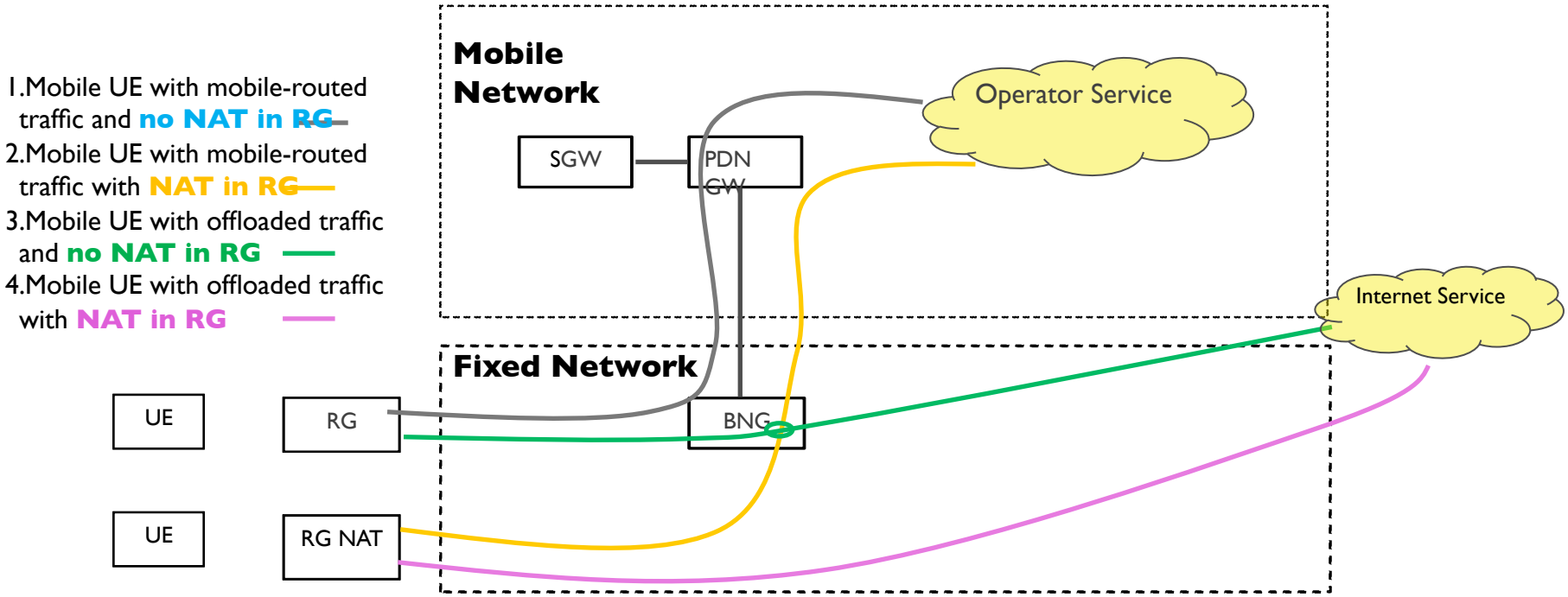


- The fixed broadband network must partner with the mobile network to perform AAA and acquire the policies for the mobile subscriber.

Key issues in FMC

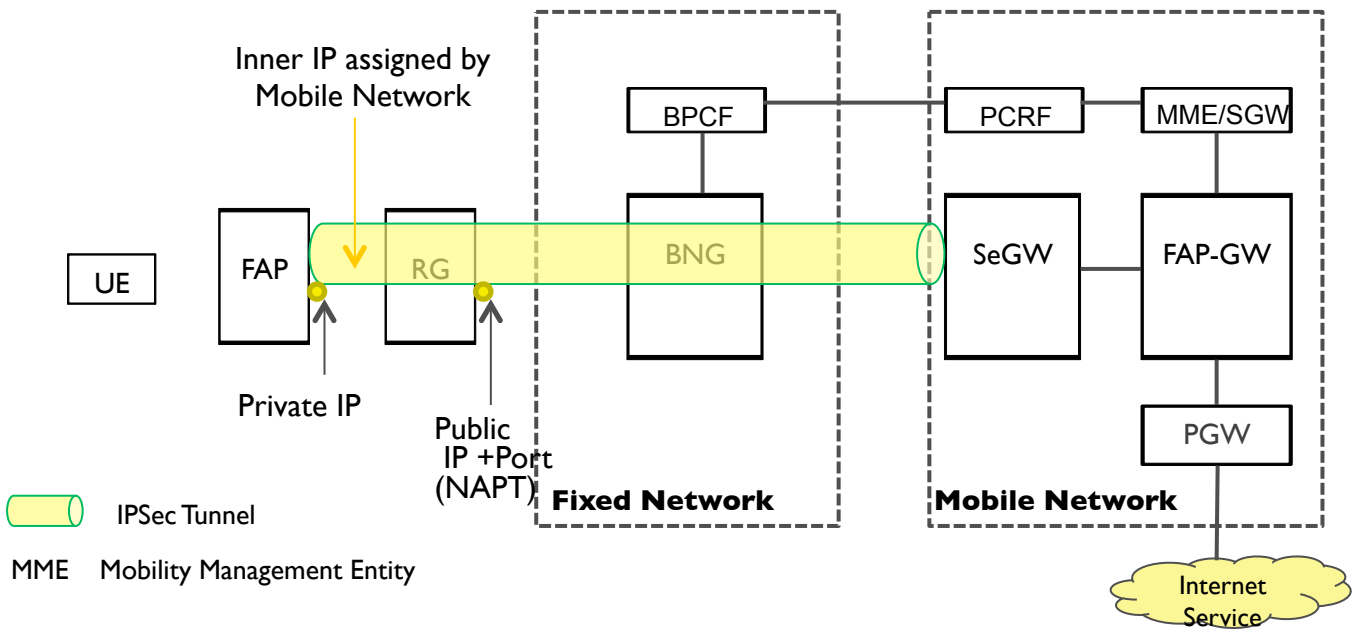
1. UE identification in FBB network
2. Femto Access Point (FAP) Management
3. Device type identification
4. Carrier Grade NAT (CGN) related issues
5. UE mobility in FBB network
6. Flow mobility between different interfaces

Issue 1: UE identification FBB network



- Key requirements:
  - In FMC scenario, the policy control must be based on per-UE granularity.
  - Efficient packet inspection deployment
- Issue: Limitations with BNG implementations for per-UE granularity enforcement due to address sharing with NAT in RG, in case 2 and 4.

Issue 2: Femtocell AP Management



- Key requirements:
  - Inter-operators subscribers policy exchange (the private and public addressing which rely on NA(P)T, must be coordinated cross operators);
  - Femtocell AP must be identified for management.
- Issues:
  - Binding the port number after NA(P)T for special Femtocell AP is needed;
  - Binding the FAP's Public IPv4 address and the UE's inner-IPv4 address is needed.

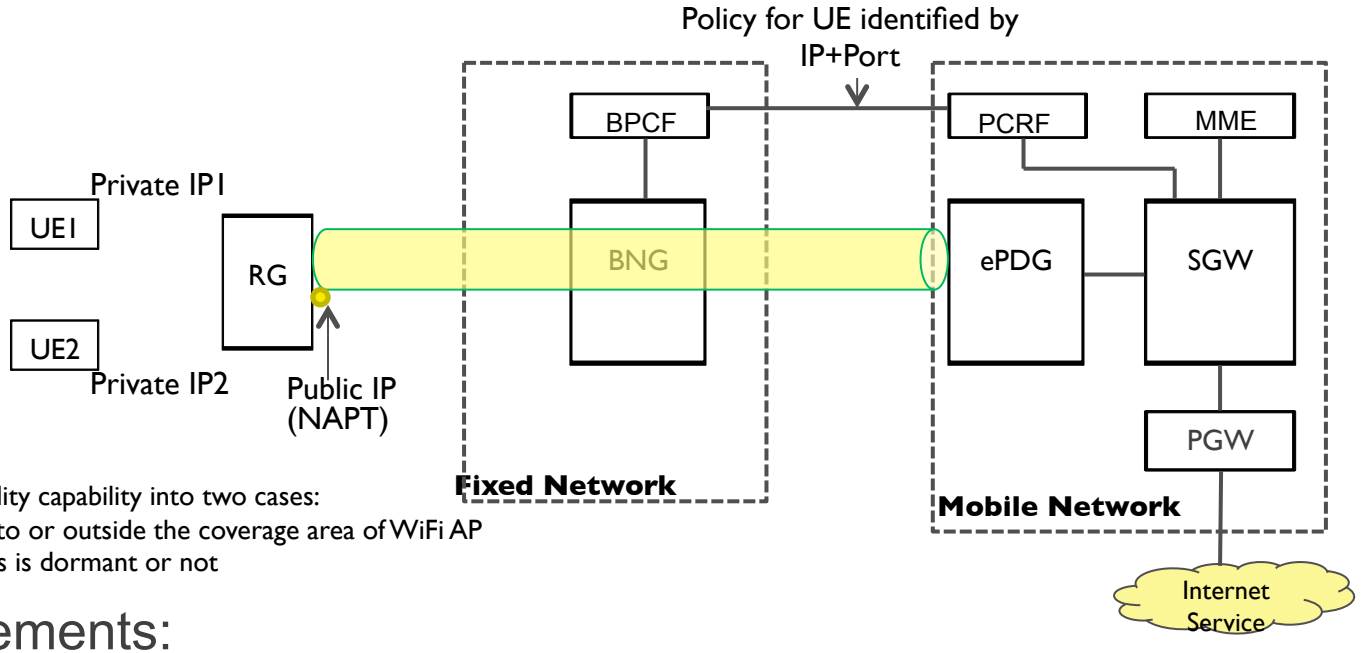
Issue 3: Device type identification

- Key requirements:
  - Only special traffic from special devices, such as mobile phone, need policy control and management. For example, 3GPP service from mobile phone.
- Issue:
  - In the current WiFi network, the device type information is transparent to the fixed broadband network, because only IP and port information is used for identification.

Issue 4: CGN related issues

- Requirements:
  - Long lived IPsec or TLS connection across Carrier Grade NAT (CGN) can not be flushed.
- Issues:
  - Currently most NAT implementations would flush all sessions after they reach 24 hours, regardless of the state of the session.
  - The session flush will cause more attachment signaling to be introduced in order to re-establish UE's sessions.

Issue 5: UE mobility in FBB network



We divide the mobility capability into two cases:

1. UE is moving into or outside the coverage area of WiFi AP
2. UE's WiFi access is dormant or not

- Requirements:
  - The UE identification must be consistent between the FBB network and the mobile network for policy exchange, even when UE is moving.
- Issues:
  - Because plenty of UEs are in AP coverage at different time slot , it is possible that the same UDP port will be used for different UEs. If the UE identification can not be updated in time based on the status, the PCRF will be confused about which policy is used.

Issue 6: Flow mobility between different interfaces

- Requirements:
  - Traffic offloading requires the ability to move the traffic flows from one interface to the other interface of the UE.
  - The type of flows to be moved depends on the policy and should be dictated by the mobile operators.
- Issues:
  - No flow mobility protocol has been applied for offload traffic.

IETF Advanced Mobility

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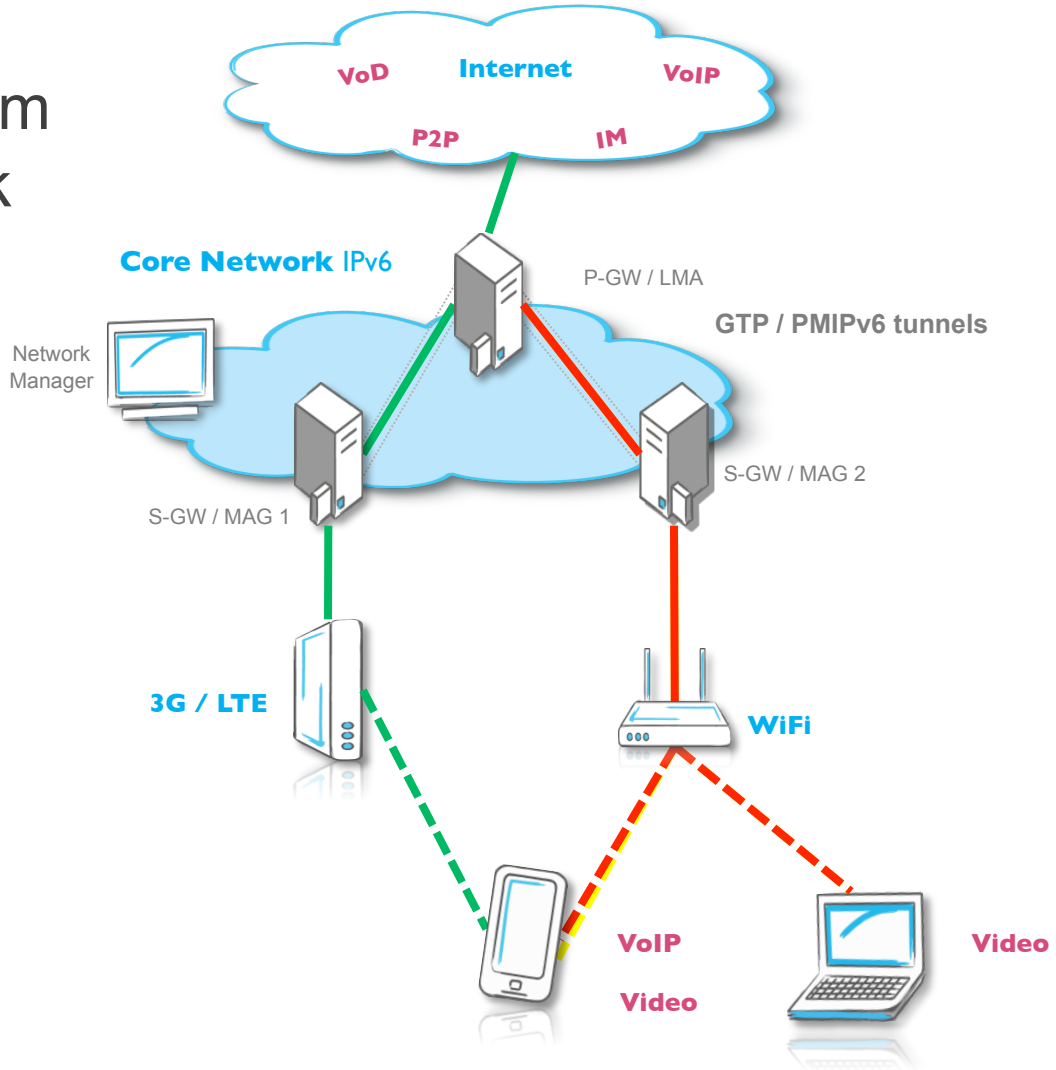
IP Flow Mobility (IFOM)

IP Flow Mobility (IFOM)

- Seamless and selective switching of a single application from one access network to another, leaving other IP Flows untouched
- Several standardization efforts (IETF NETEXT, 3GPP SA2 SAMOG, MAPCON, MAPIM, NBIFOM)
- Enables new tiered-services by applying user-specific policies and tariffs
- Network-based IP flow mobility (NB-IFOM) (PMIP/ GTP-based) and client-based (DSMIP-based) solutions exist

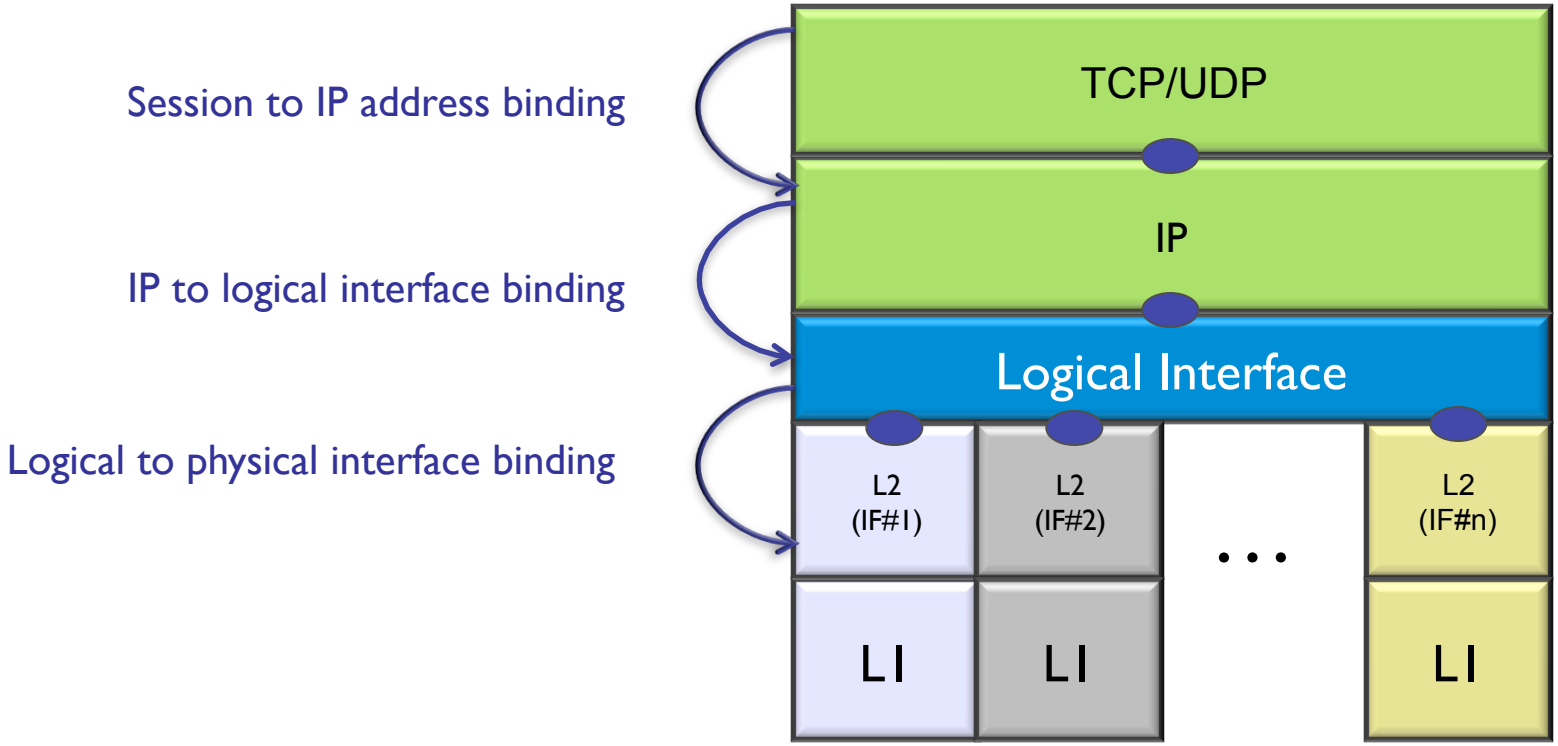
IP Flow Mobility

- Traffic can be steered from one radio access network to another to achieve:
  - Offloading
  - Service differentiation
  - Security
  - Seamless inter-RAT handover / session continuity



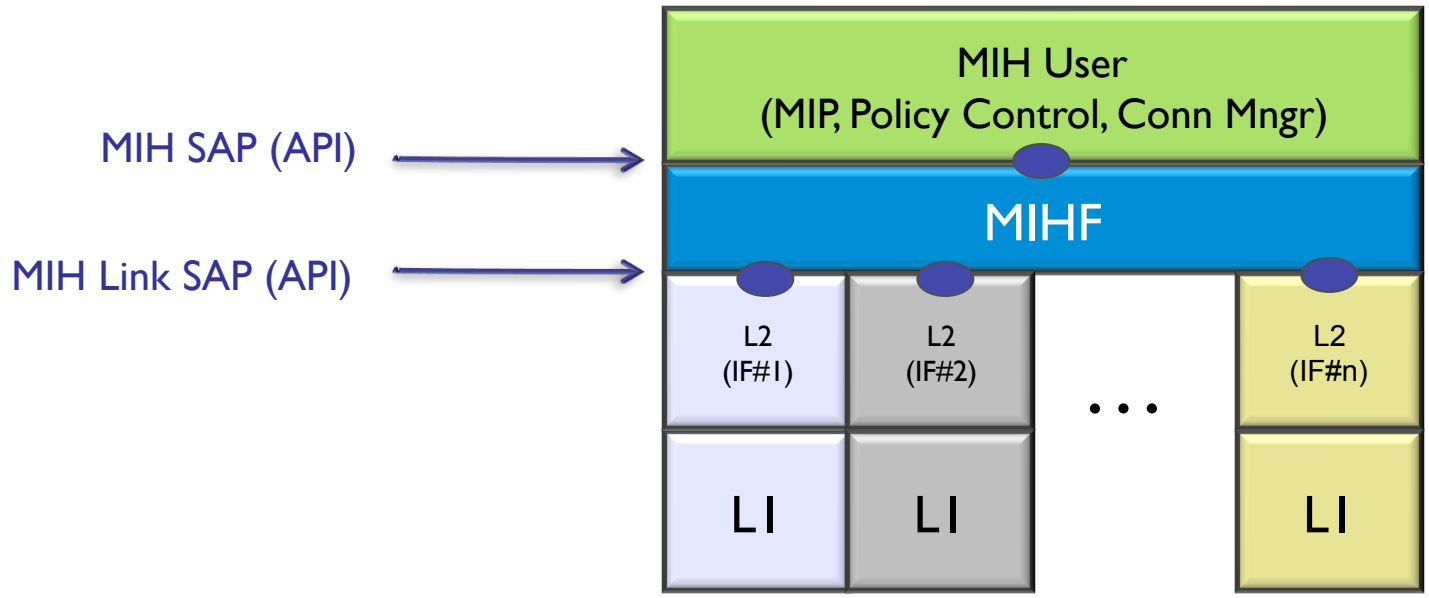
Logical Interface – Data Plane

- Allows hiding L2/L1 changes to IP stack and maintaining session bindings active
- Permits forwarding traffic to different access networks regardless of the original IP address assignment



802.21 MIHS – Control Plane

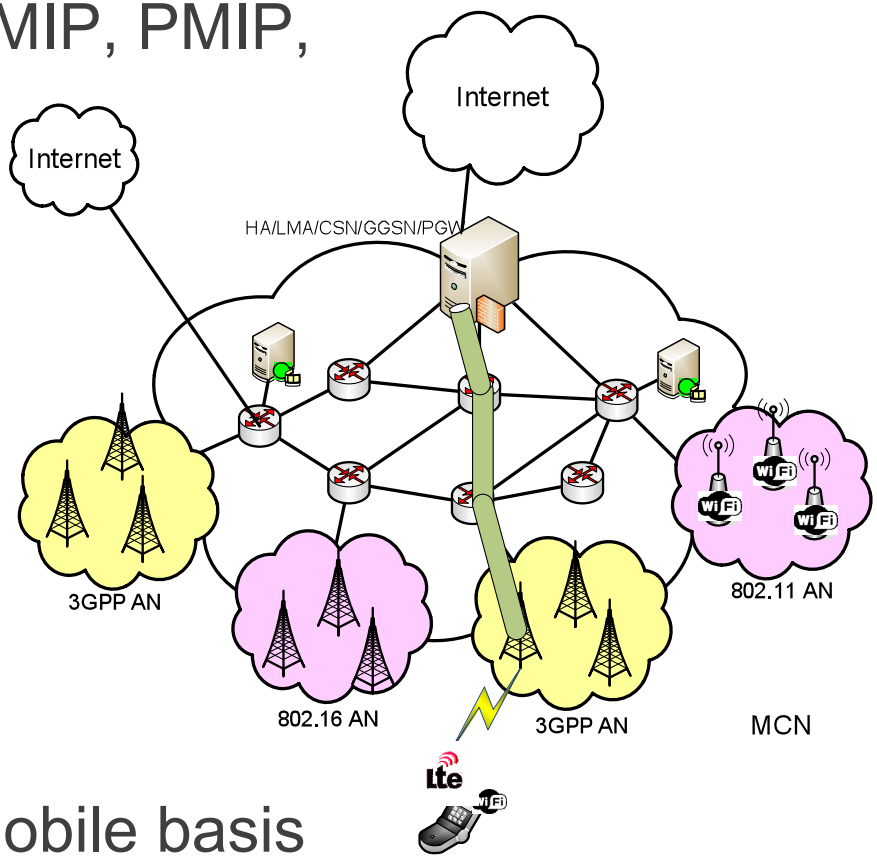
- Provides predictive signaling that can proactively trigger handovers or flow mobility and hence enhance QoE (ES)
- Allows a better control of lower layers to enforce Operator and User's policies (CS)
- Provides information about available access networks (IS)



IETF Dynamic / Distributed Mobility Management (DMM)

DMM Problem Statement

- Current IP mobility approaches (MIP, PMIP, GTP, etc) rely on a central anchor point
- Issues:
  - Sub-optimal routing to edge content (CDN)
  - Reliability
  - Scalability
  - Lack of granularity
    - Mobility offered on a per-mobile basis
  - Signaling overhead
  - Heterogeneous networks (small cells, integrated BS/AP, etc)

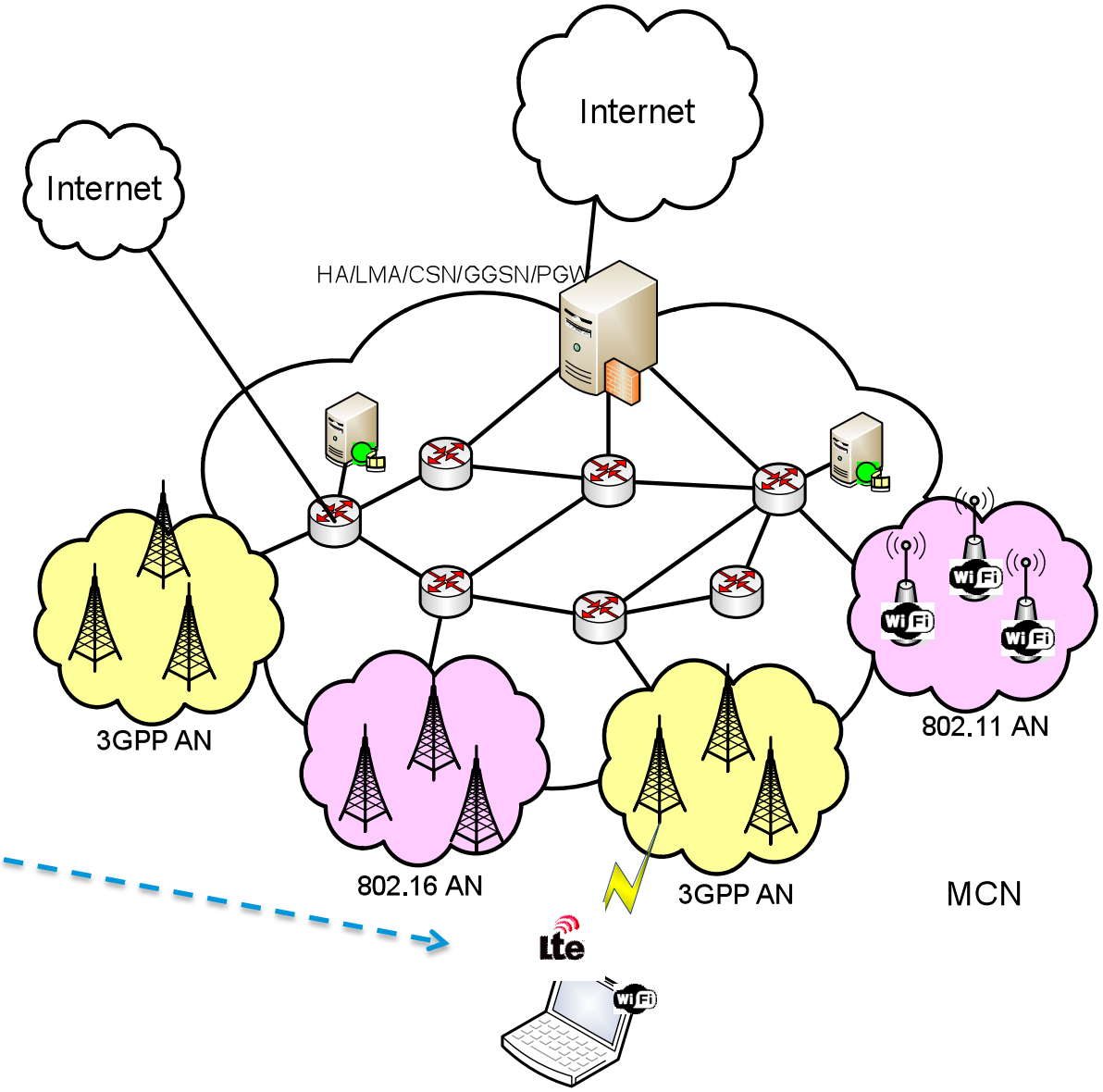


Use Case 1: **Low Mobility User**

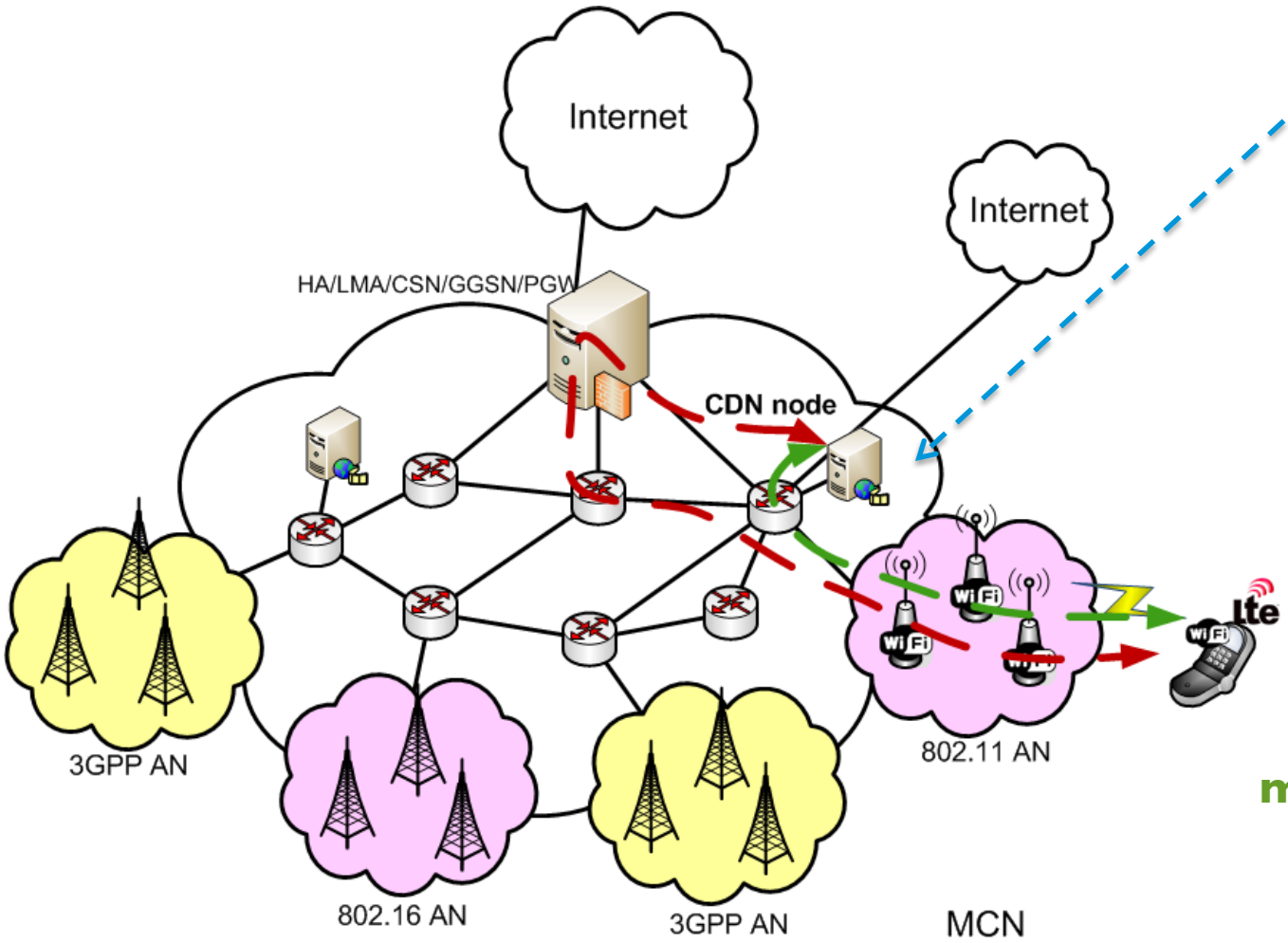
Always-on mobility support is quite a big overhead here

Start with mobility support off, enable it on demand (if needed)

User seldom moves (if at all)



Use Case 2: **Local Content/Breakout**



User is accessing content locally available or a local breakout to the Internet is available (LIPA/ SIPTO)

Centralized anchoring is sub-optimal

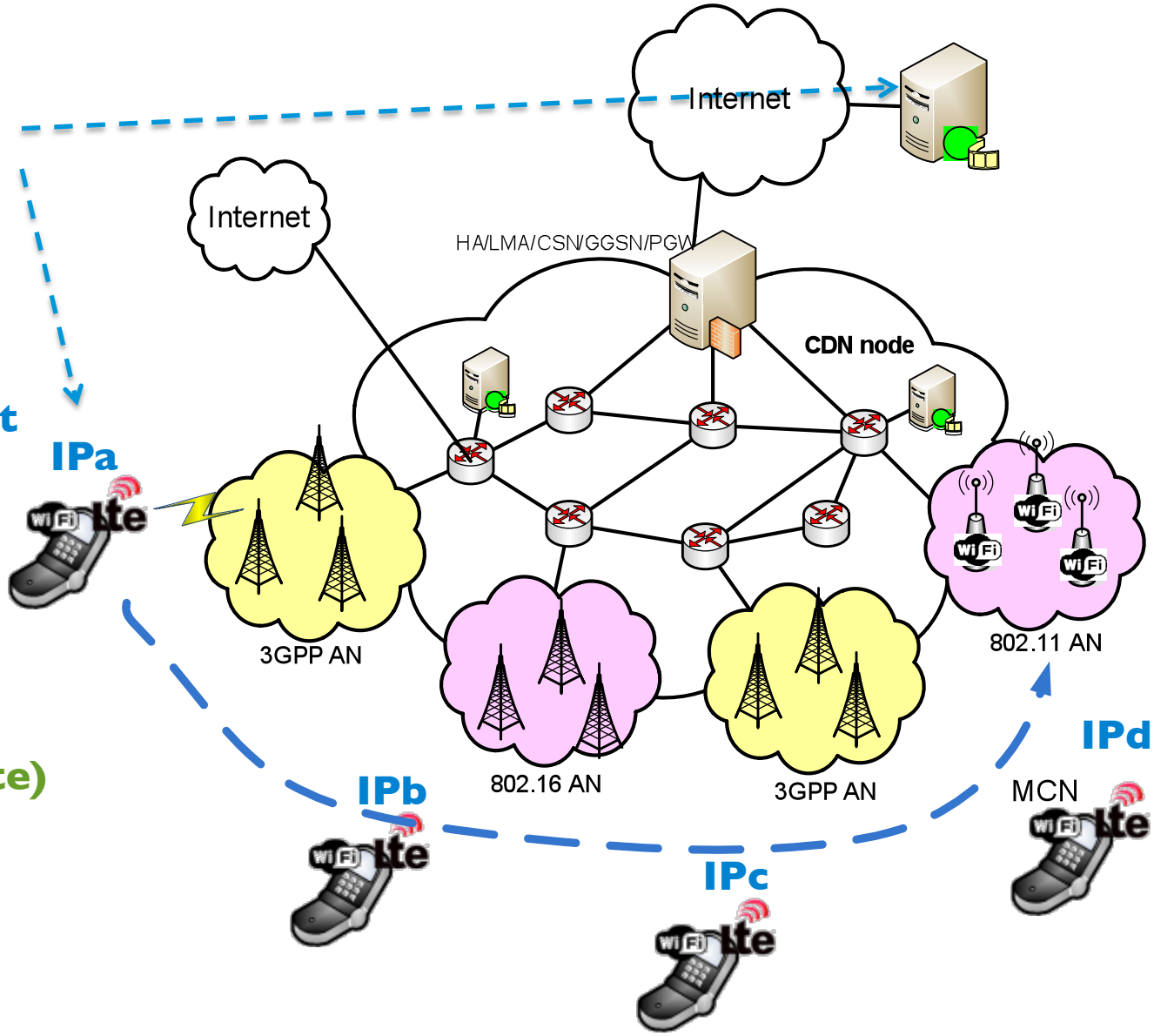
Push data plane mobility anchors to the edge of the network

Use Case 3: **Mobility-enabled Apps**

Application is able to handle and survive an IP address change

Current architectures provide sufficient support w/o mobility

Do not trigger mobility management (signaling and state) unless required

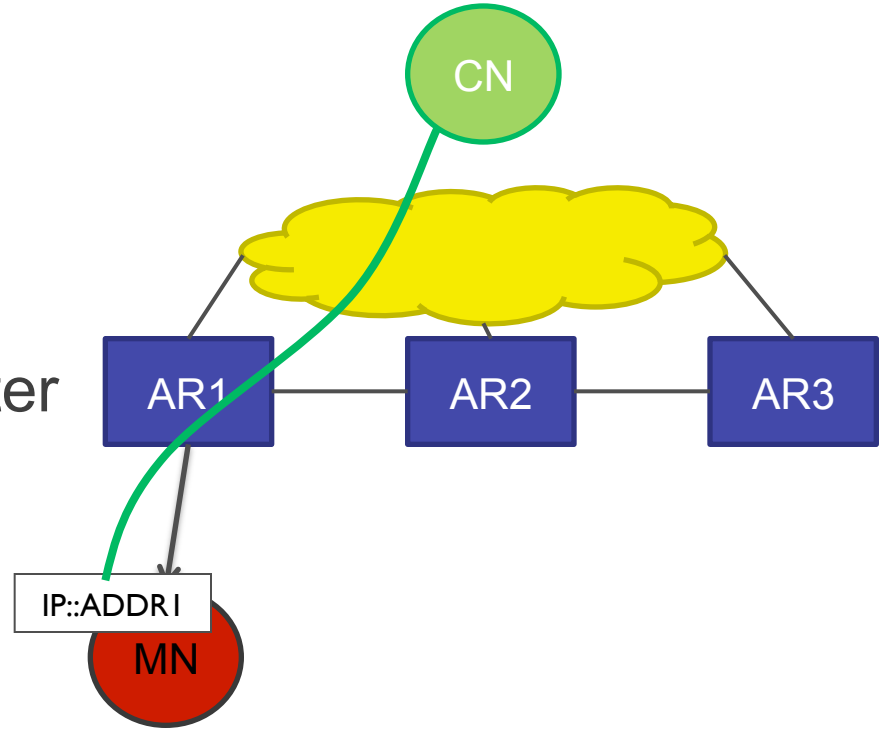


Dynamic/Distributed Mobility Management (DMM) – IETF Solutions

- Pushing mobility anchors to the edge of the network
  - Distributed Mobility Management
- Mobility should only be enabled when it is actually needed
  - Applications that cannot survive an IP address change
  - Only needed if the user really moves
  - Dynamic Mobility Management
- People usually refer to both concepts as **DMM**
- Network-based and client-based proposals exist

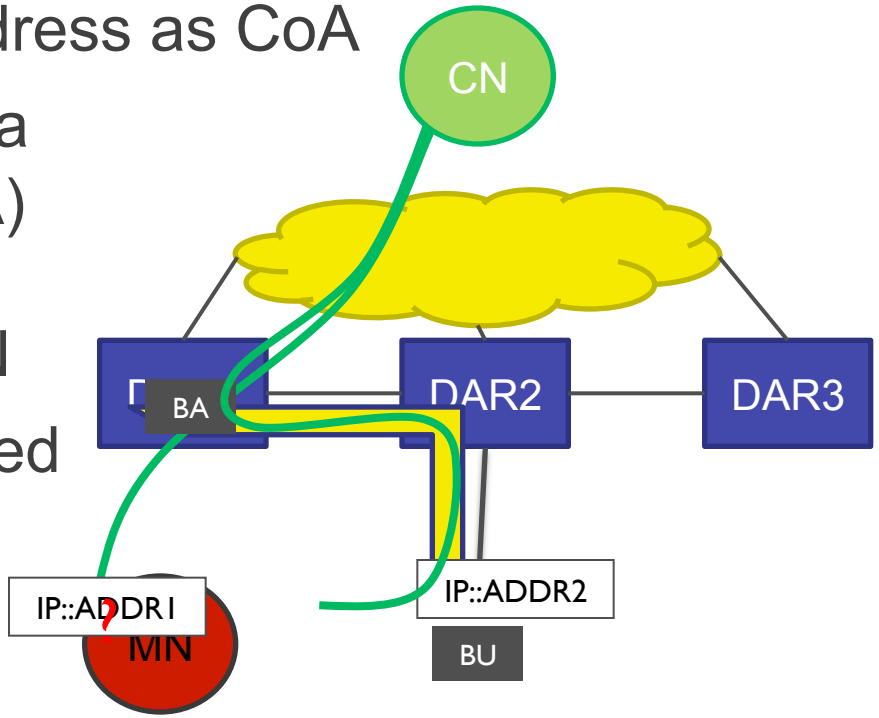
DMM (1)

- When a Mobile Node attaches to an Access Router (AR) it gets an IP address which is topologically anchored at the AR
- MN starts communications with the configured address
- The AR acts as standard IP router
  - MN can send/receive traffic with no packet encapsulation



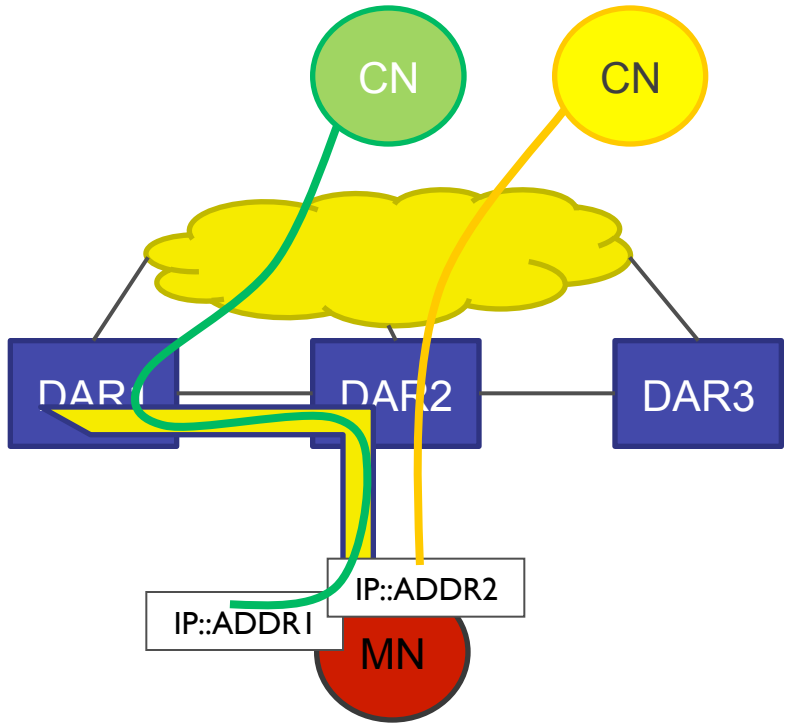
Client-based DMM (2a)

- Upon changing point of attachment, the MN gets another IP address
- To maintain ongoing flows, the MN sends a Binding Update (BU) to the previous Dynamic AR (DAR), indicating the new address as CoA
- The anchor DAR replies with a Binding Acknowledgment (BA) and a tunnel is established between anchor DAR and MN
- Existing flows can be redirected to the new MN's location



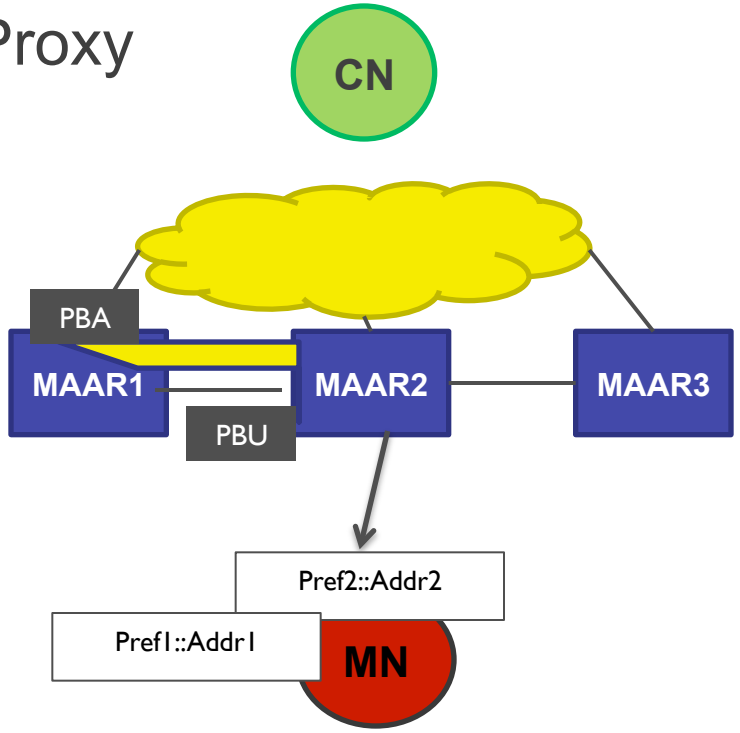
Client-based DMM (3a)

- New communications are started using the IP address acquired from the DAR the MN is currently attached to
- The new flow does not require tunnels nor special packet handling



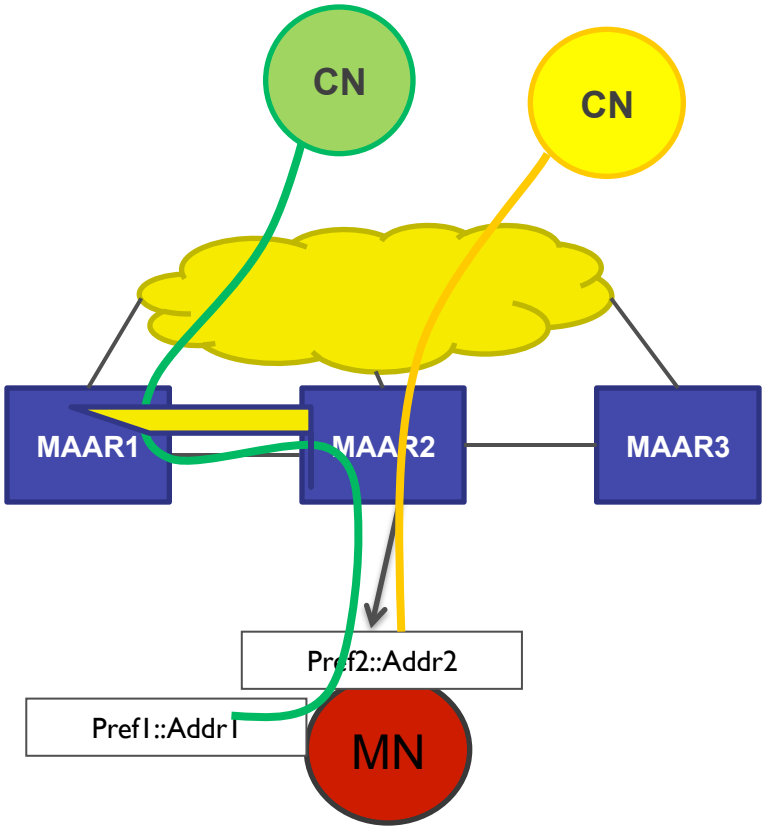
Network-based DMM (2b)

- Upon changing point of attachment and to maintain ongoing flows, the Mobility Anchor & AR (MAAR) sends a Proxy Binding Update (PBU) to the previous MAAR
- The anchor MAAR replies with a Proxy Binding Acknowledgment (PBA) and a tunnel is established between anchor MAAR and MN
- The previous address together with a new address are assigned and existing flows can be redirected to the new MN's location



Network-based DMM (3b)

- New communications are started using the IP address acquired from the MAAR the MN is currently attached to
- Tunnels are only used in the network side and the control of the DMM is also on the network
- The new flow does not require tunnels nor special packet handling



OmniRAN and IP Mobility

- Heterogeneous devices require integrated solutions to inter-RAT mobility
  - IETF – LIF: guidelines only
  - IETF – DMM: not addressing issues below L3
  - IEEE 802.21: partial solution to mobility
  - IEEE 802.3, 802.11, 802.15, 802.16, etc. & 3GPP: out of scope
- **Natural vacuum here for OmniRAN to fill in!**

Questions and Answers

http://wirelessman.org/sg/het