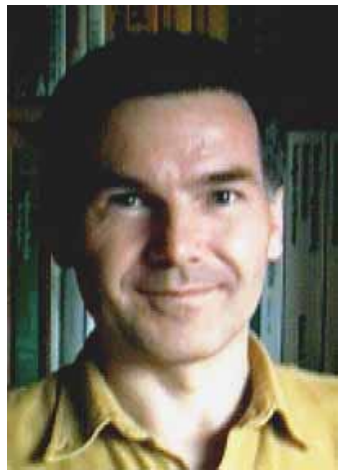
WiMAX Network Architecture

Max Riegel, 2005-12-02

SIEMENS

Max Riegel
http://www.max.franken.de/



"Let's have fun, serve our customers and make money."

1984	**Dipl-Ing (TU) Electrical Engineering (TU Munich)**
1984-1993	**Philips Kommunikations Industrie, Nuremberg** Videoconferencing Systems & Videotelephony Hardware & software & systems development *1987-1993: Head of development laboratory*
since 1993	***'on the Internet'*** ***1994-2001: Founder and head of "Kommunikationsnetz Franken e.V.", a non-profit community ISP***
1994-1997	**Teleprocessing Systeme, Cadolzburg** *Head of Hardware development for data communication*
since 1998	**Siemens Information and Communication, Munich** *1998-2000: Expert for Internet Standardization* *2000-2001: Director 'Internet Standardization'* *2001-2004: Head of 'Advanced Standardization'* *since 2004: VP 'Mobile Network Standardization'* *- coordination of mobile network standardization* *- managing activities in IETF, ITU-T, IEEE802, WiMAX* *- vice chair WiMAX NWG*

SIEMENS

Outline

- WiMAX Applications and Markets
- WiMAX Forum and IEEE802.16 Standardization
- The path towards ‘Mobile WiMAX’
- WiMAX Network Architecture Tenets
- WiMAX Network Reference Model
- WiMAX Mobility Management
- WiMAX Interworking with 3G
- Open issue: Indoor penetration
- Conclusion

SIEMENS

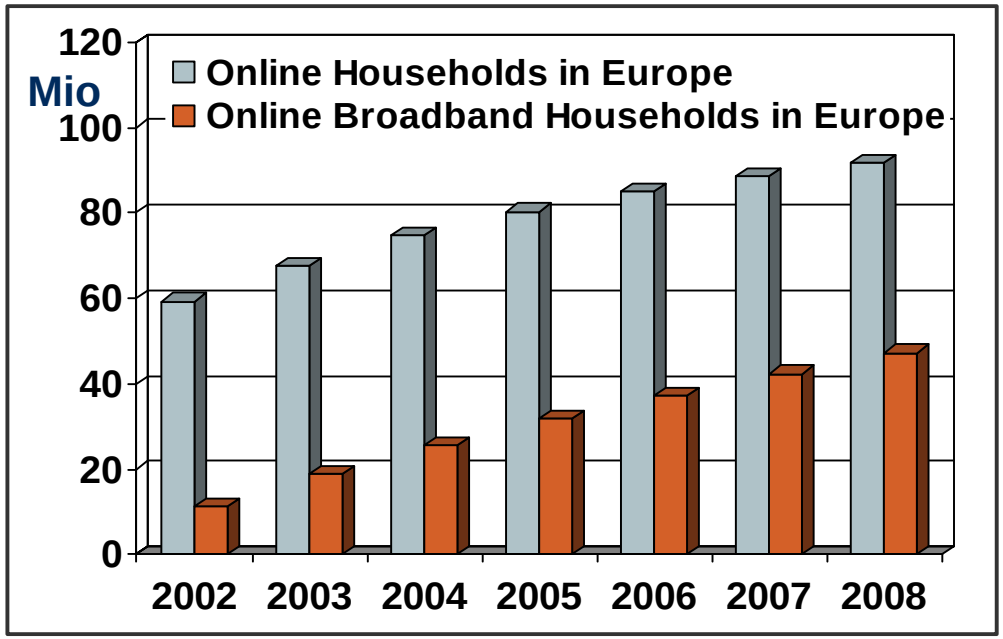
WiMAX Applications and Markets

SIEMENS

The WiMAX market may be quite large

The broadband divide:

Until 2008 only half of all Internet households will have broadband access.



Source: Jupiterresearch, Nov 2003

Reasons:

- **too complicated**
  - especially for the 55+
- **too expensive**
  - especially for the casual user

There is a huge business to serve the other 50% of all households with broadband Internet access

- **Usually a wireless technology provides a more user-friendly and less expensive for casual user solution.**
- **Many ‘casual users’ may be willing to pay a monthly fee of up to 20€ for their flat-rate broadband Internet access.**

SIEMENS

Key figures of a wireless DSL system

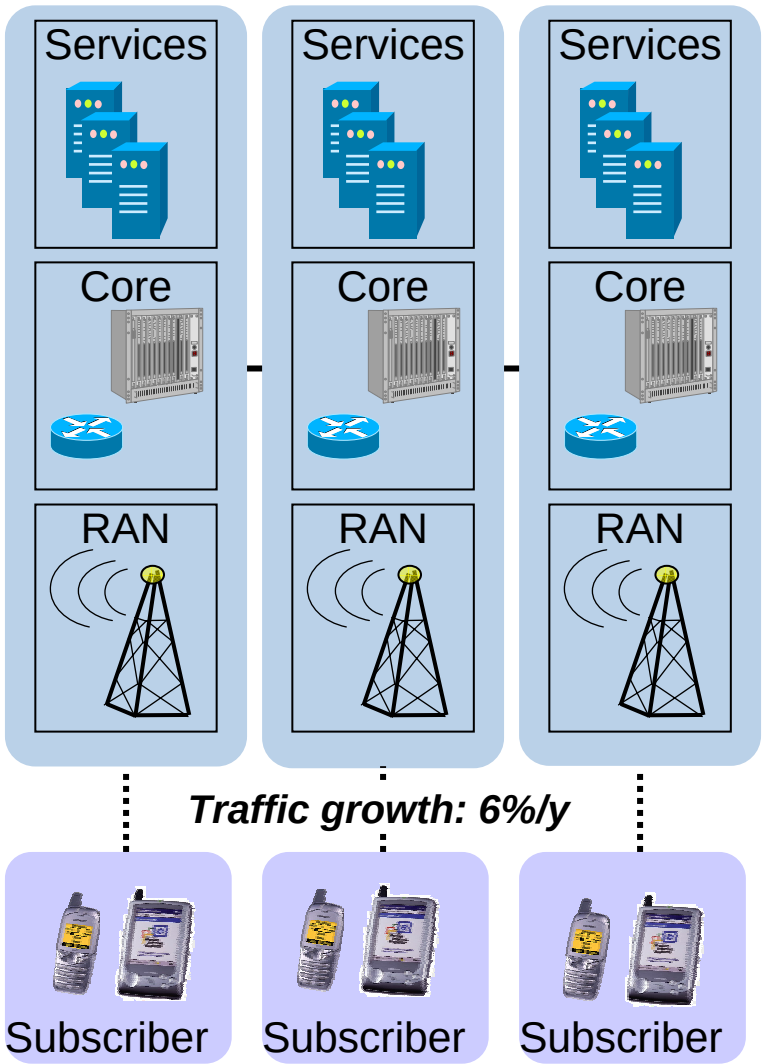
- **Bandwidth per user (DL): 1 Mbit/s (like wireline DSL)**
- **Maximum number of customers per ‘base-station’:**
  - assuming an aggregate DL capacity of 20 Mbit/s per base-station
  - a multiplexing factor of 25
    (statistical multiplexing gain when combining the traffic of several users)
    - usual figures for wireline DSL: 30 - 150
    - according to traffic statistics from Korean DSL users:
      20 000 DSL customers are producing a peak data rate of 500 Mbit/s
- **each base-station may serve at least 500 customers (even more when going for the ‘casual-user’)**
- **required cell size:**
  - assuming a density of 1200 households/km^2 (urban area)
  - 15% penetration for wireless DSL
- **Coverage area per base station: about 1,7 km (diameter)**

These figures are nicely fitting into available radio technologies

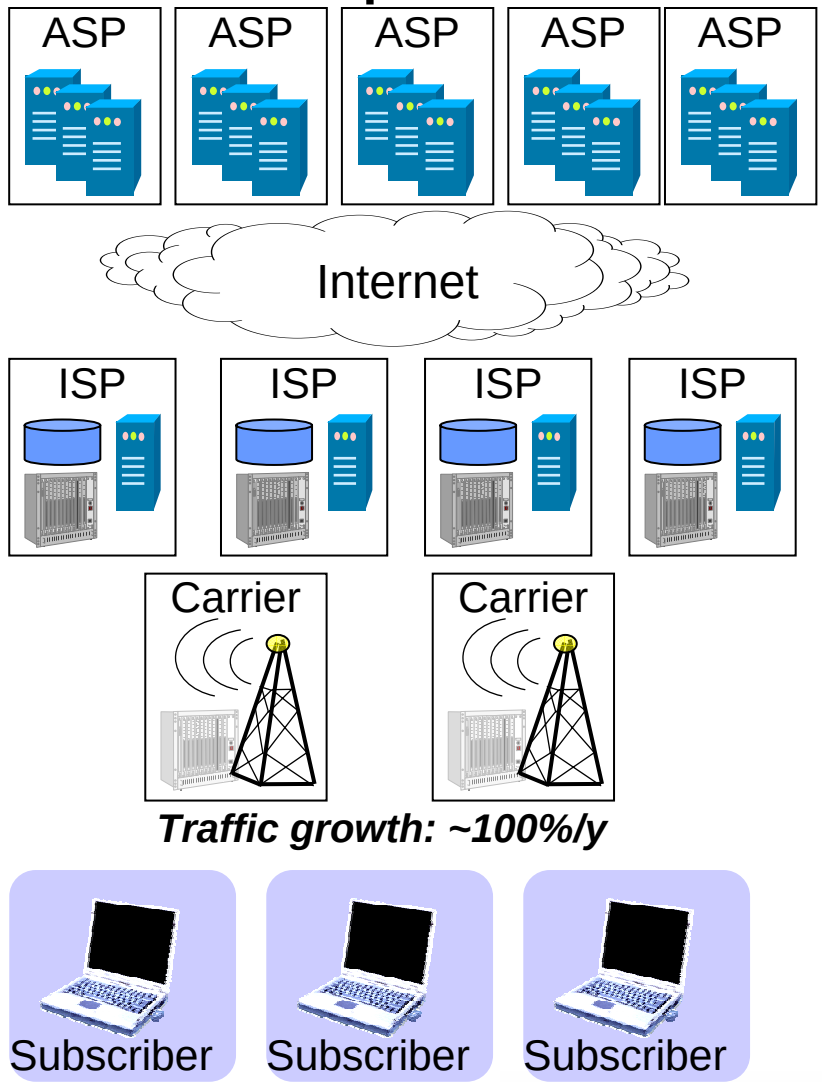
SIEMENS

WiMAX is a different mobile business

MNO value chain

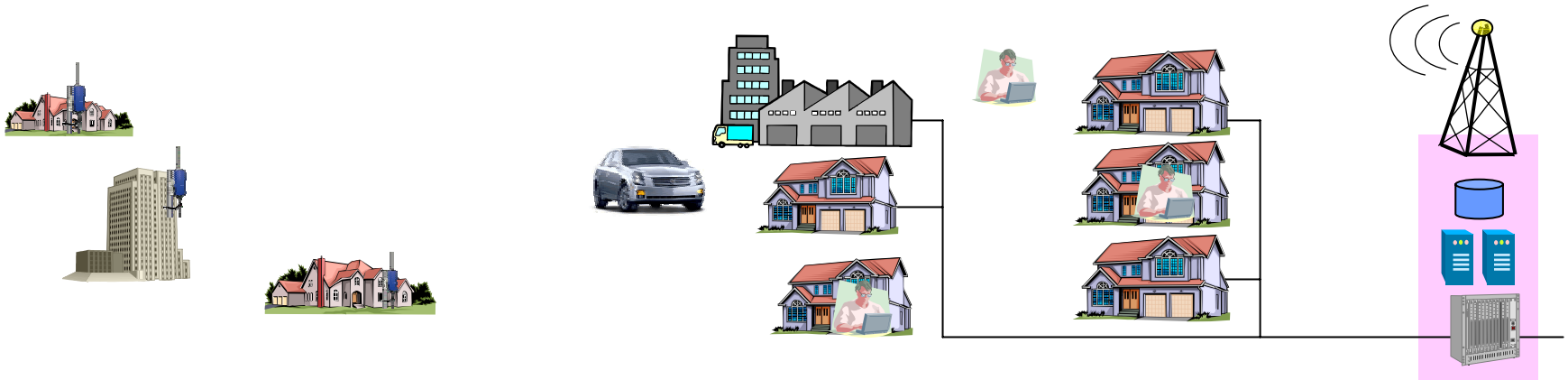


WiMAX value pattern



SIEMENS

Wireless DSL deployment evolution



Today's broadband providers are tied to their wires

- **serving consumers and enterprises inside their reach**

A wireless DSL system allows to extend the DSL business serving customers without appropriate wires, and additionally also...

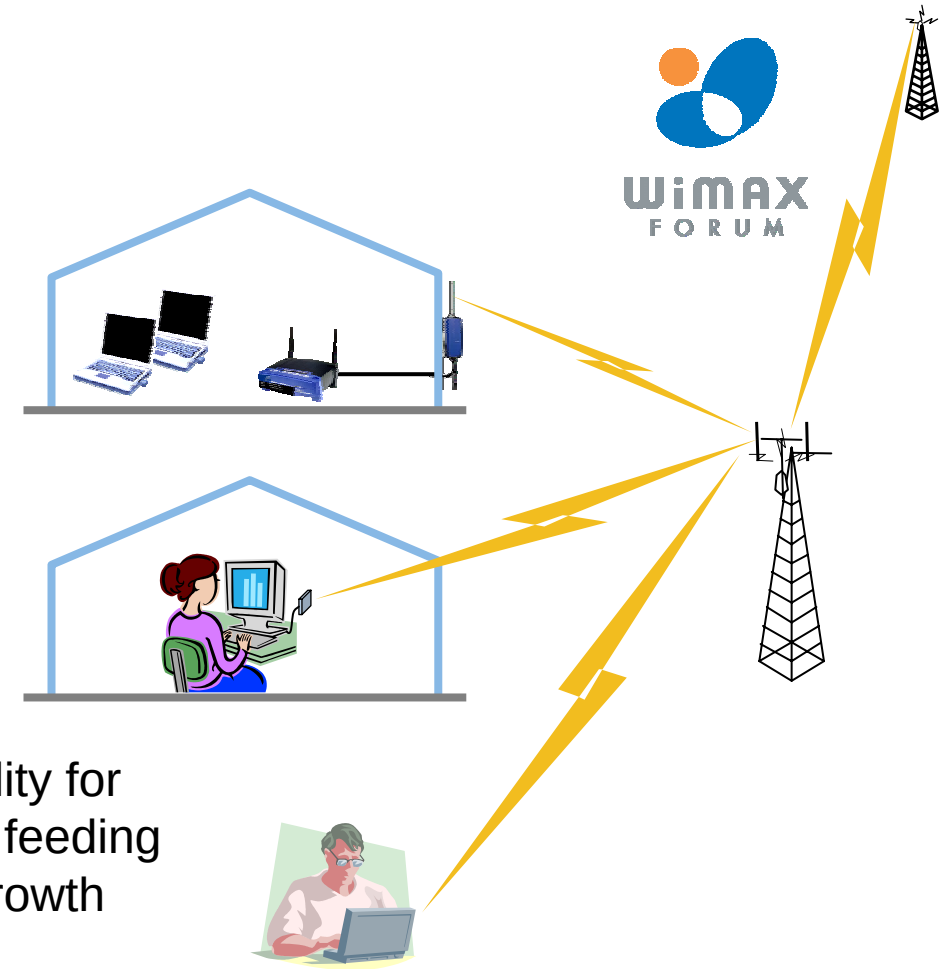
- **addressing customers looking for a more easy-to-use solution,**
- **providing portable and mobile access**

All together may be necessary for a successful business case!

SIEMENS

The evolution of WiMAX

- **Backhaul feeding**
  - PtP links for fixed infrastructure
  - Dedicated market w/ limited size
- **Fixed Wireless Access**
  - Wireless local loop, hotspot feeding
  - Suffers from poor CPE handling
- **Nomadic Access (Hotzone)**
  Indoor CPE thanks to better radio
  CPE may be integrated into terminal
  - Most promising for mass market
- **Portable Access**
  Handover function enabling data mobility for road warriors, train feeding and coach feeding
  - Mobility enables persistent market growth

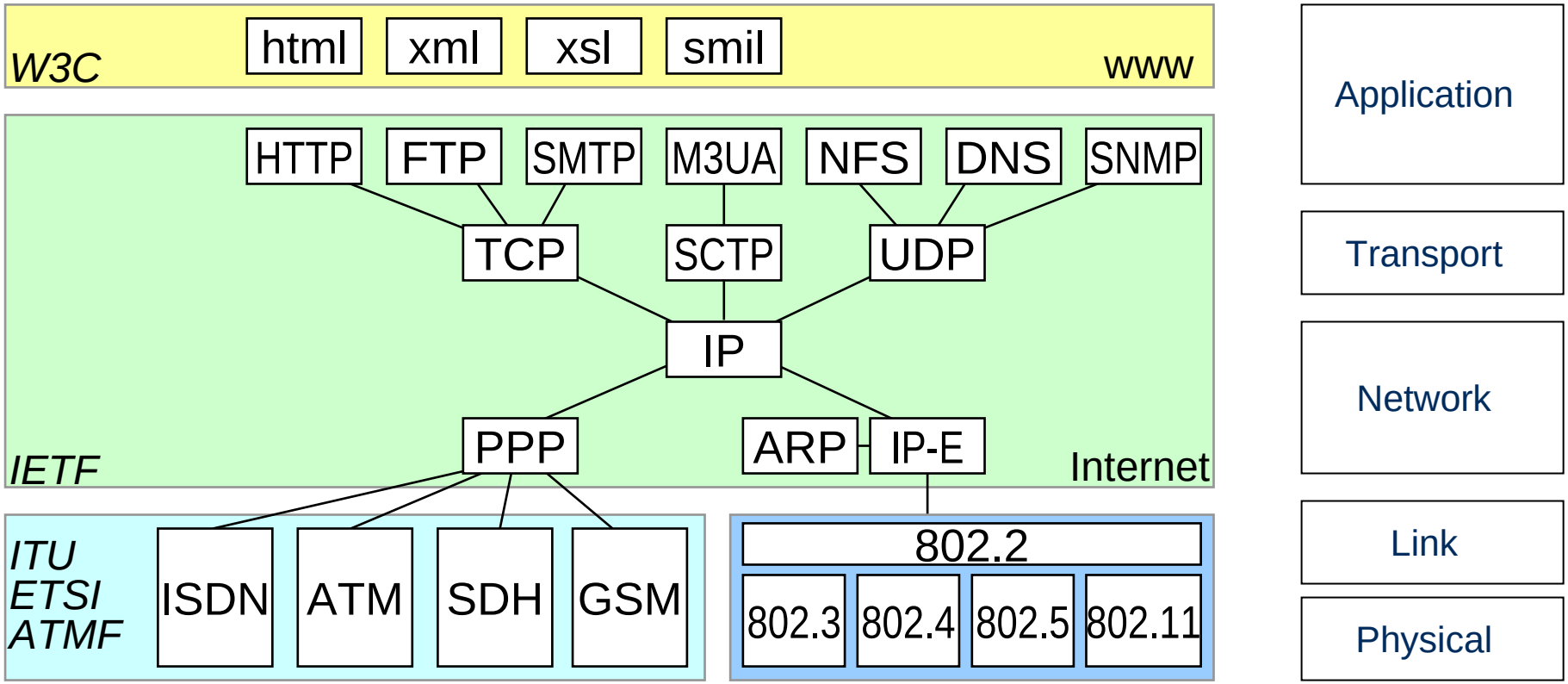


SIEMENS

WiMAX Forum and IEEE802.16 Standardization

SIEMENS

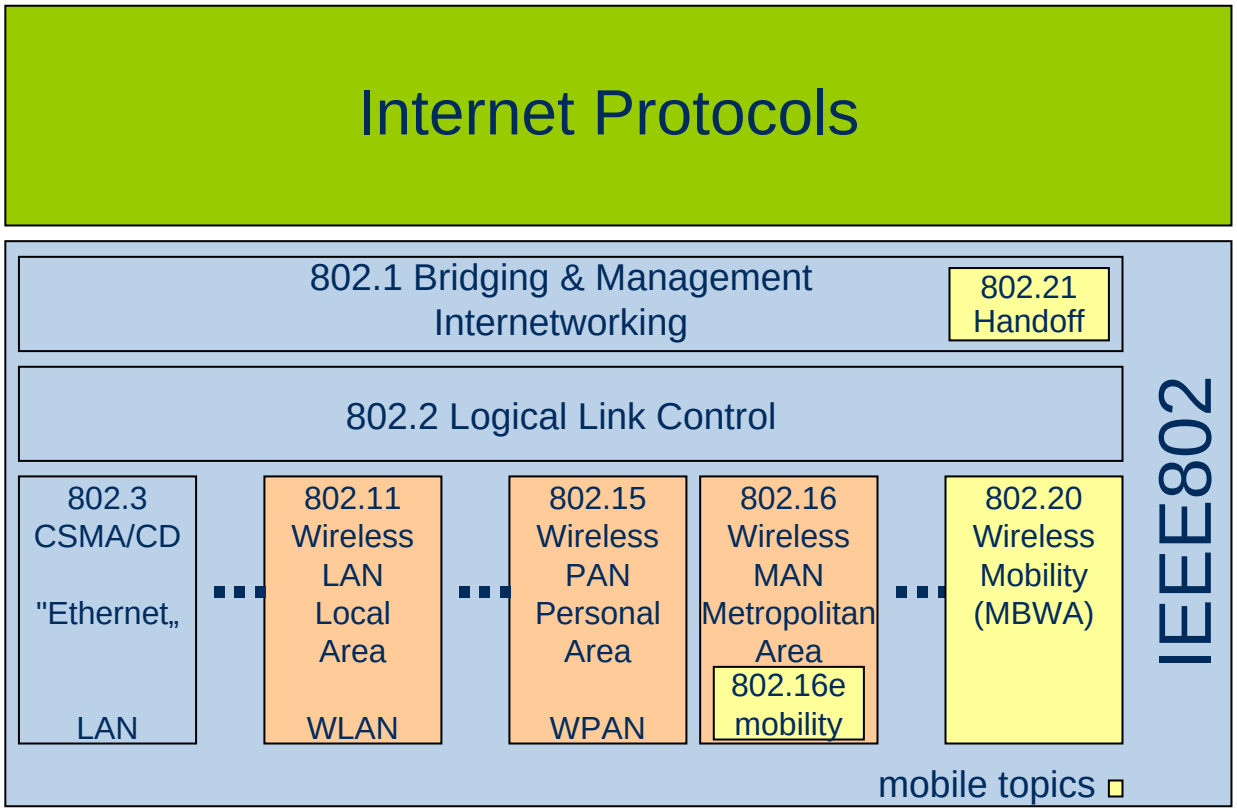
- the other leg of the Internet

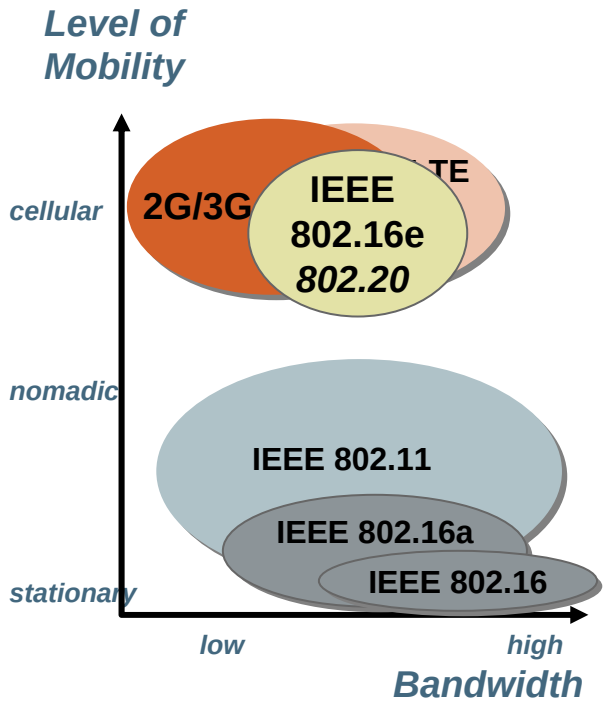


- **IEEE Project 802 develops LAN and MAN standards,**
  - Only Link and Physical Layer of the OSI reference model
- **Some standards published by ISO as international standards**
- **International participation, some meetings held outside the U.S.**

SIEMENS

Wireless Mobility in IEEE802





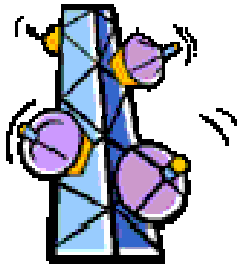
IEEE802 has set up two groups with nearly identical focus

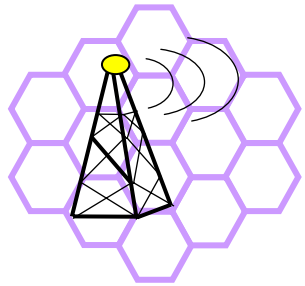
- **IEEE802.16e with backward compatibility to fixed and nomadic**
- **IEEE802.20 from ground up new for enhanced mobility**

IEEE802.20 is somewhat more challenging, but not ready before 2007

SIEMENS

IEEE 802.16 – 2004: *'One standard fits all'*

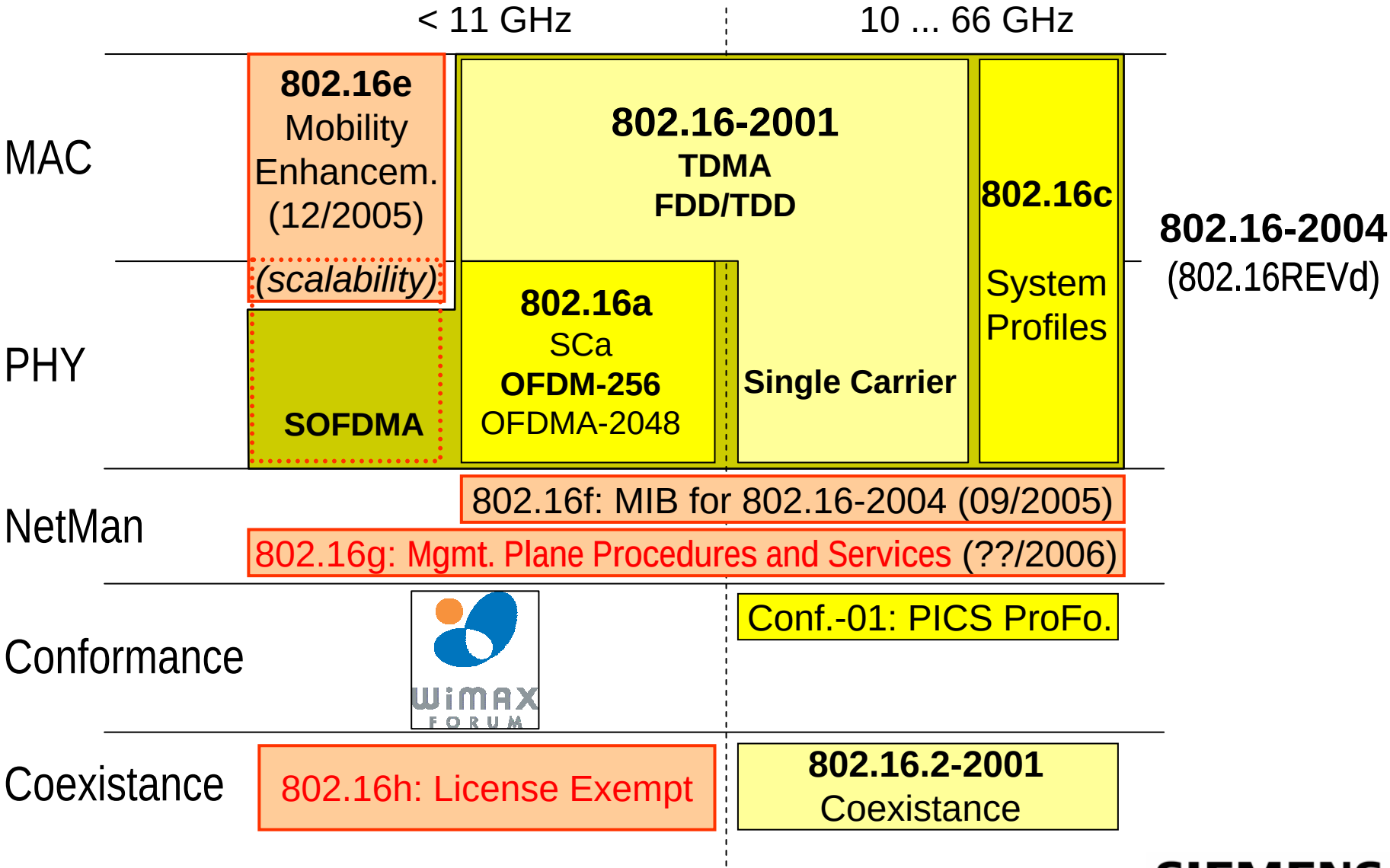




	Feeding	FWA	Cellular
Completed	December 2001	January 2003	June '04/Mobility '05
Spectrum	10 - 66 GHz	< 11 GHz	< 6 GHz
Channel Conditions	Line of Sight Only	Non Line of Sight	Non Line of Sight
Bit Rate	32 – 134 Mbps in 28MHz channel bandwidth	Up to 75 Mbps in 20MHz channel bandwidth	Up to 15 Mbps in 5MHz channel bandwidth
Modulation	Single Carrier QPSK, 16QAM, 64QAM	OFDM 256 sub-carriers QPSK, 16QAM, 64QAM	1x Scalable OFDMA QPSK, 16QAM, 64QAM
Mobility	Fixed	Fixed	Portable Mobile (up to 120 km/h)
Channel Bandwidths	20, 25 and 28 MHz	Scalable 1.5 to 20 MHz	Scalable 1,25 to 20 MHz
Typical Cell Radius	2-5 km	7 to 10 km Max range 50 km	1-5 km

SIEMENS

IEEE 802.16 Broadband Wireless Access



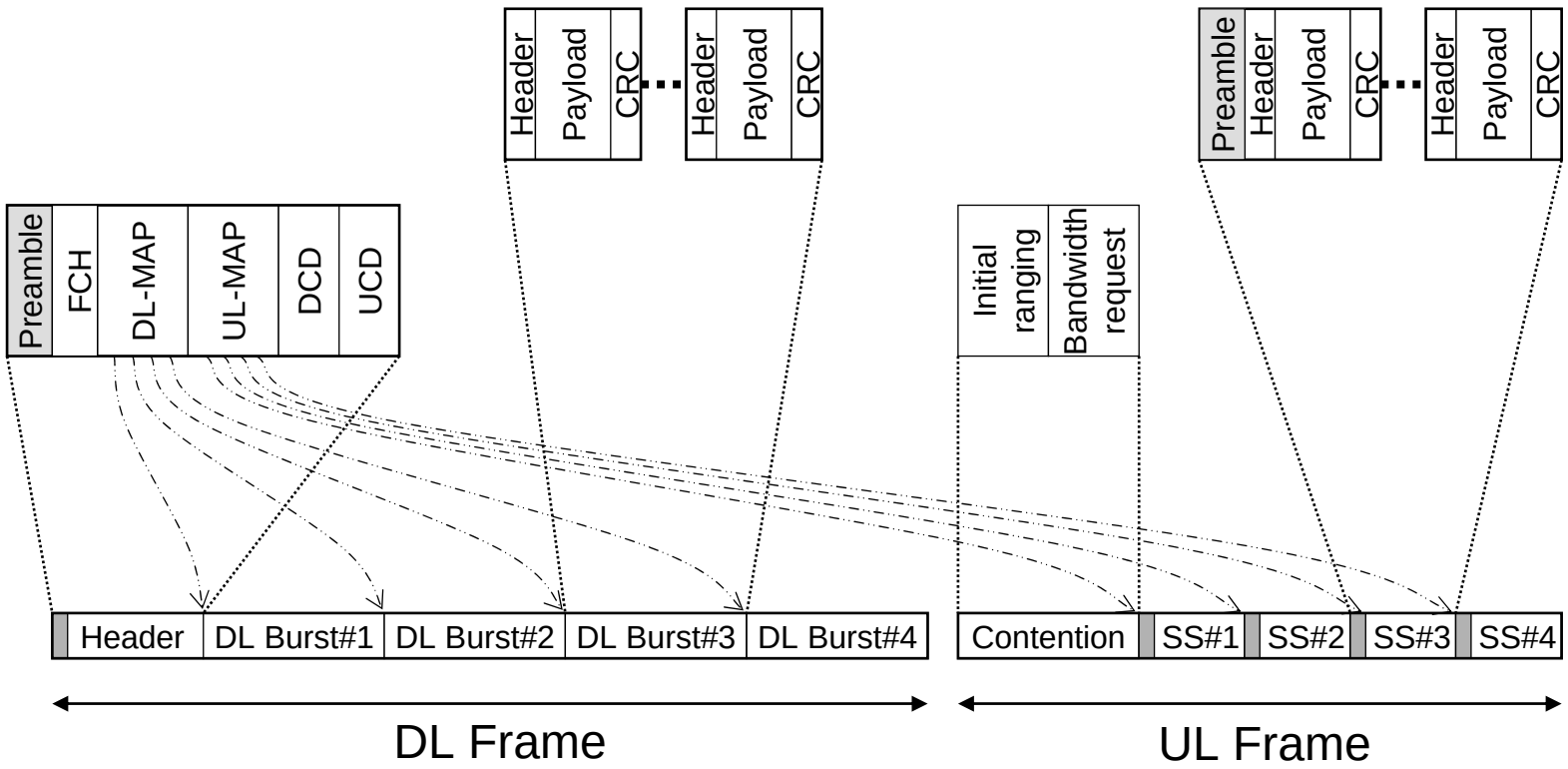
SIEMENS

IEEE802.16 Network Entry

- **Downling Channel Synchronization**
  - MS scans for DL channel to which it is able to synchronize and decode DCD and UCD for modulation and other parameters
- **Initial Ranging**
  - MS adjusts transmission power and timing adjustments by probing the BS in the initial ranging interval.
- **Capabilities Negotiation**
  - MS transmits its capabilities (modulation levels, coding schemes and rates, duplexing methods) to the BS
- **Authentication**
  - MS initiates authentication exchange (EAP) to establish authenticated session and associated key material.
- **Registration**
  - MS initiates registration by sending message with MAC capabilities.
- **Transport Connection Creation**
  - The BS establishes the preprovisioned services flows by sending request message to the MS (=> CIDs)
- **Convergence Sublayer**
  - MAC layer sets up the convergence sublayers by configuring the packet classifiers and eventual header compression over the air.

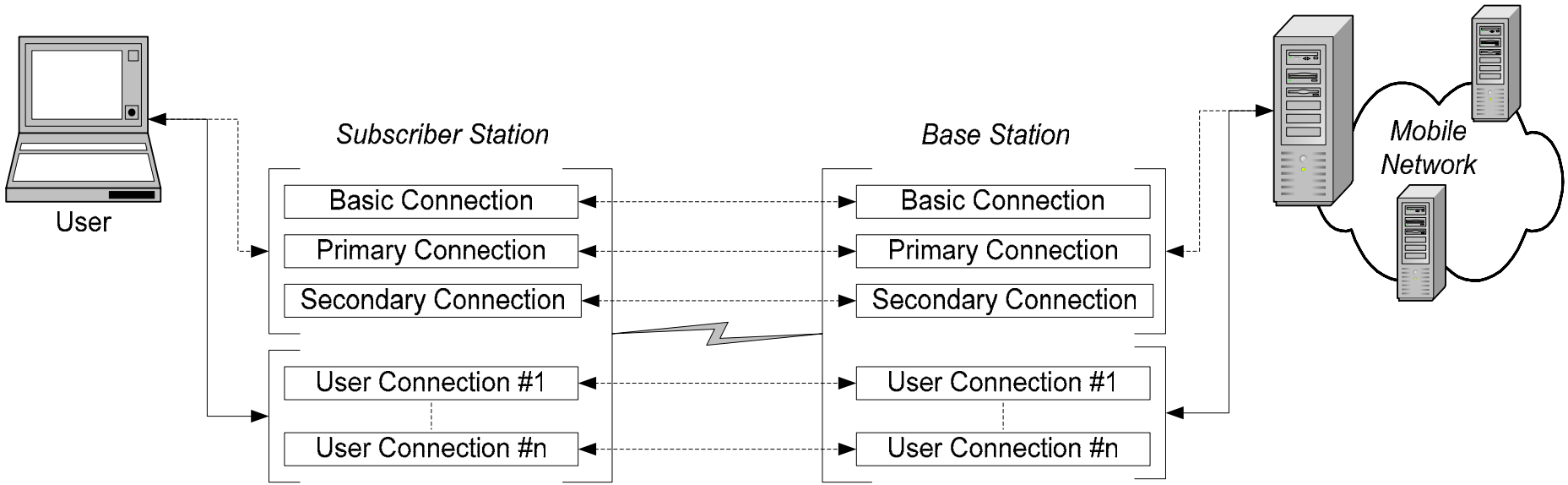
SIEMENS

IEEE802.16 MAC Frame Structure



SIEMENS

IEEE802.16 MAC: Connections over the Air

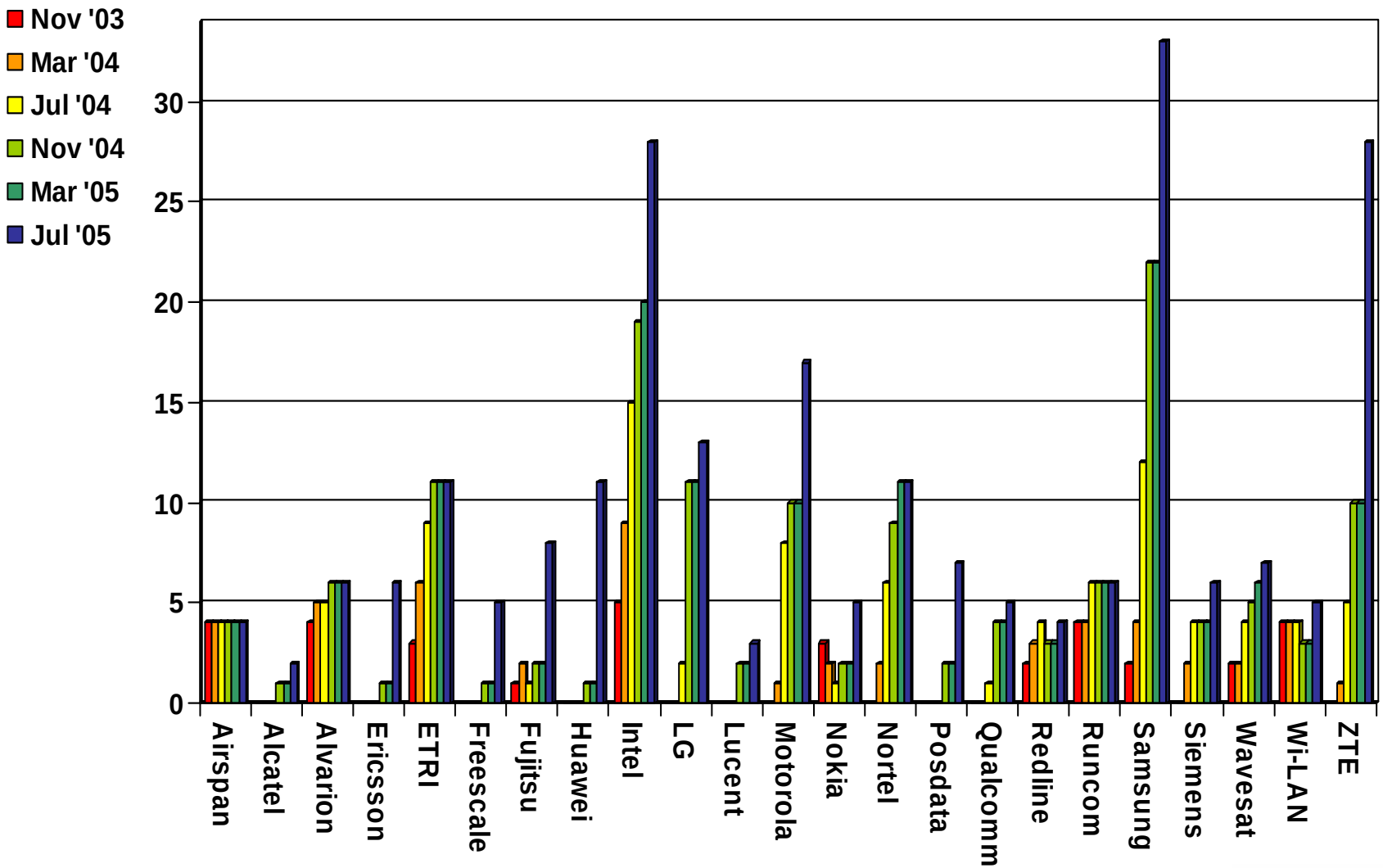


MAC Layer implements connection-oriented paradigm over the air

- **Three management connections**
- **Zero or more user connections**
- **Managed Quality of Service on a per connection basis**

SIEMENS

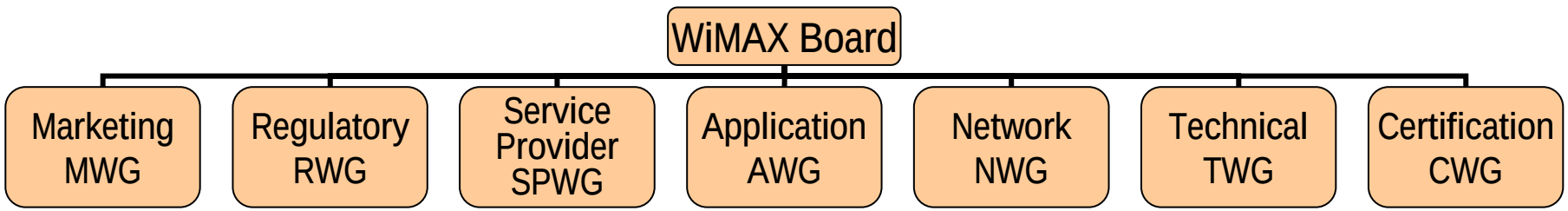
Voting membership in IEEE802.16



SIEMENS

Worldwide Interoperability for Microwave Access

- **The purpose of WiMAX is to promote deployment of broadband wireless access networks by using a global standard and certifying interoperability of products and technologies.**
  - Support IEEE 802.16 standard
  - Propose and promote access profiles for their IEEE 802.16 standard
  - Certify interoperability levels both in network and the cell
  - Achieve global acceptance
  - Promote use of broadband wireless access overall
- **WiMAX Forum grew up to more than 350 members within in this year**
- **Chaired by Intel**

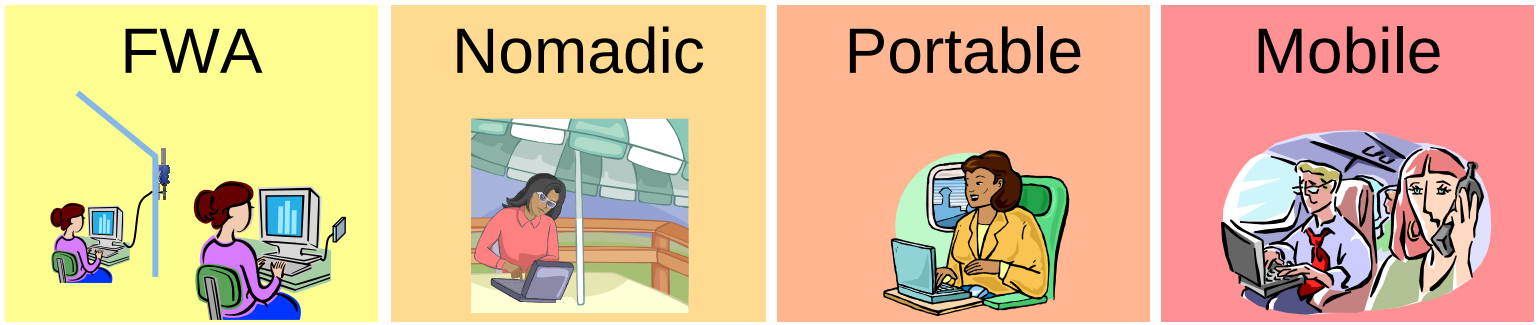


SIEMENS

The path towards ‘Mobile WiMAX’

SIEMENS

WiMAX Evolution Path



OFDM-256

SOFDMA

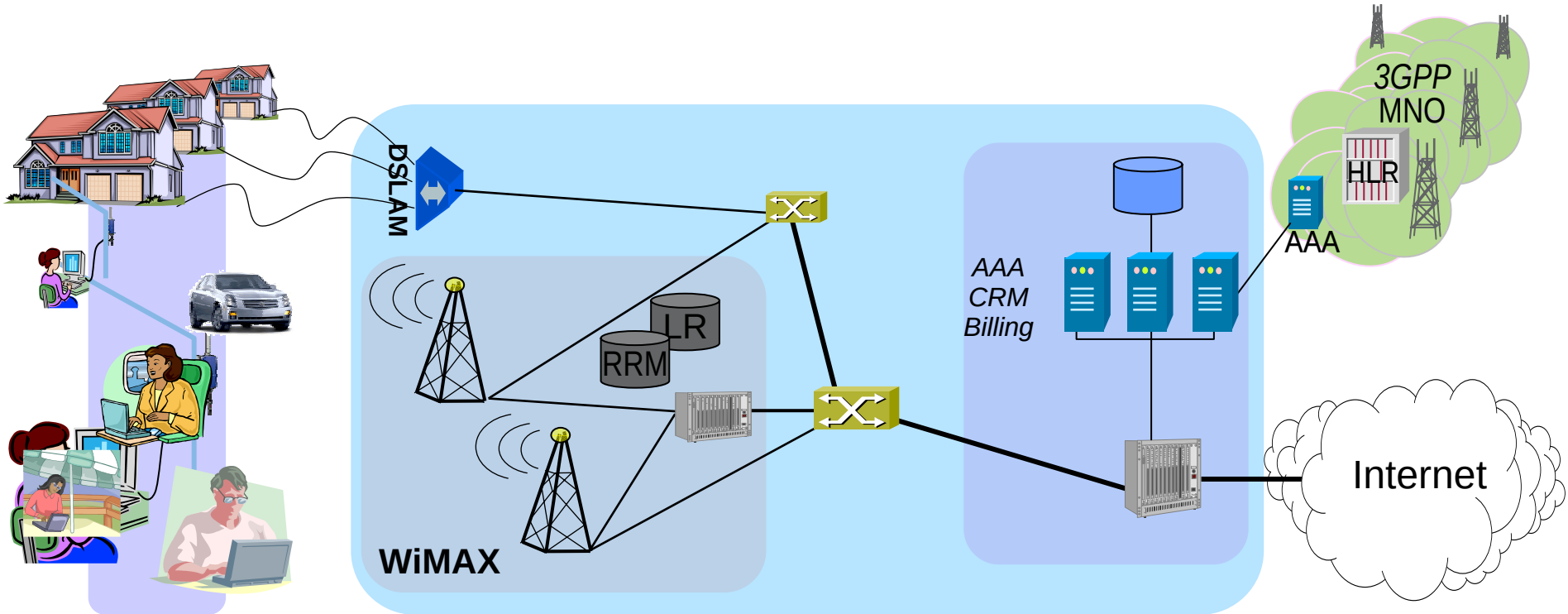
Mobile Access Network required

Simple Mobility

Full Mobility

SIEMENS

Evolving from fixed to mobile: WiMAX becomes a full-blown mobile network



IP
PP
PPP
802
802

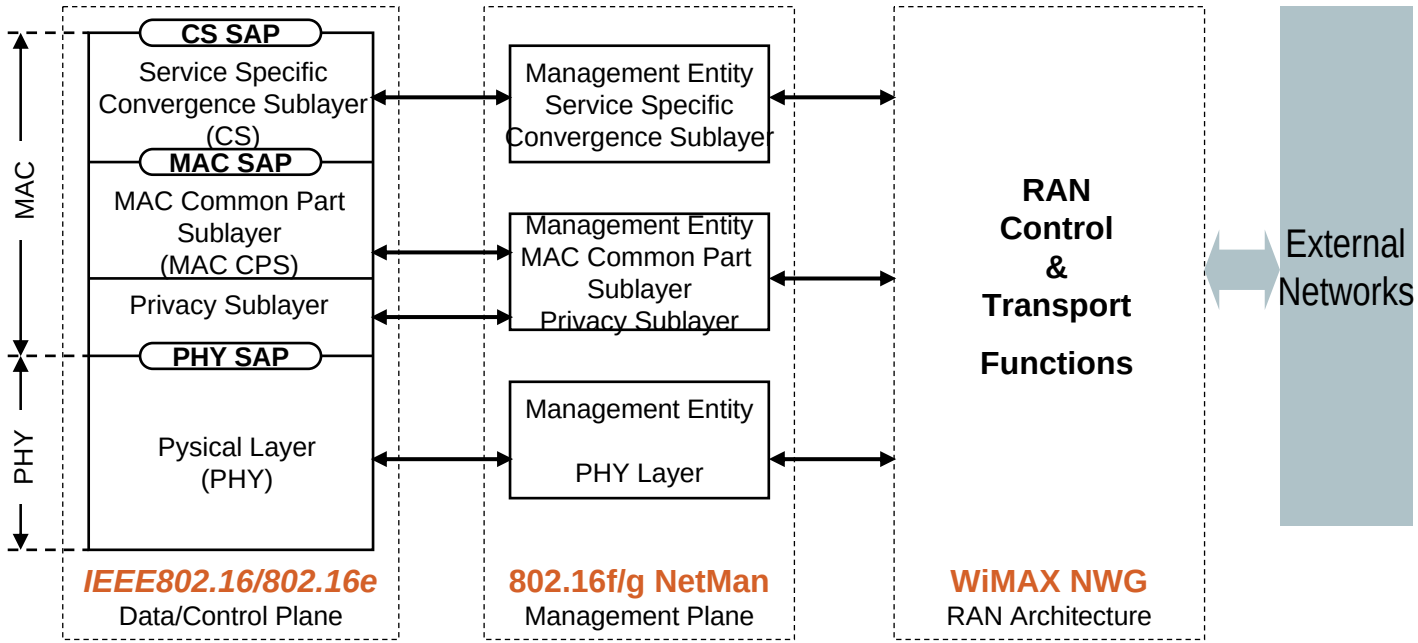
???

nomadic/portable/mobile WiMAX network

IP	IP
PP	
PoE	
02.2	802.2
02.3	802.3

SIEMENS

Relation IEEE802.16 vs. WiMAX NWG



IEEE802.16-2004 & 802.16e define only data and control plane

Management plane functions are added by 802.16f & g (NETMAN)

IEEE P802.16 does not deal with functions usually provided by the RAN

- **The standardization of these missing parts of a portable/mobile WiMAX access network is the scope of the WiMAX NWG.**

SIEMENS

The roots of the ‘WiMAX Network WG’: WiMAX E2EARCH WG (MINA)

- **Founded by Intel in June 2004 for development of an end-to-end industry specification for WiMAX portable and mobile wireless broadband systems**
  - Address interfaces, RAN infrastructure elements and interworking - beyond the scope of 802.16
  - Provide foundation for subsequent system level interoperability specs driven through WiMAX Forum
- **Invited companies: Alvarion, Arraycomm, Alcatel, Cisco, Intel, Motorola, (Nortel, left in September ‘04) Samsung, Siemens, ZTE**
- **Process aligned to 3GPP/3GPP2 with Stage 1 (Requirements), Stage 2 (Architecture) and Stage 3 (Protocols)**
- **Fast progress and demand for more interaction with Service Provider WG led to transition into WiMAX NWG in January ’05**
- **Extremely tight schedule for NWG:**
  - Stage 2 (Architecture): E11/05
  - Stage 3 (Protocols): E07/06

SIEMENS

WiMAX Network Architecture Tenets

SIEMENS

Tenets for WiMAX RAN Architecture
(Siemens contribution to MINA; July '04)

- **WiMAX is evolving out of wireline broadband access:**
  - DSL/Cable -> FWA -> Nomadic -> Portable -> Mobile
- **Align WiMAX network architecture to common DSL/Cable architectures**
  - smaller networks may follow WiFi hotspot concepts
- **Keep regulatory issues of broadband access in mind**
  - 'unbundeled access'/'bitstream access' in Europe
  - nomadic scenario without handover
- **Support network sharing**
  - faster deployment possible
- **Do not stick with existing 3G core networks**
  - 3G optimized for small-to-medium data rates per user
  - may become too expensive for broadband usage

SIEMENS

Basic Tenets for WiMAX Network Architecture

The WiMAX NWG end-to-end architecture framework shall be modular and flexible enough to not preclude a broad range of flexible implementation and deployment options ranging from:

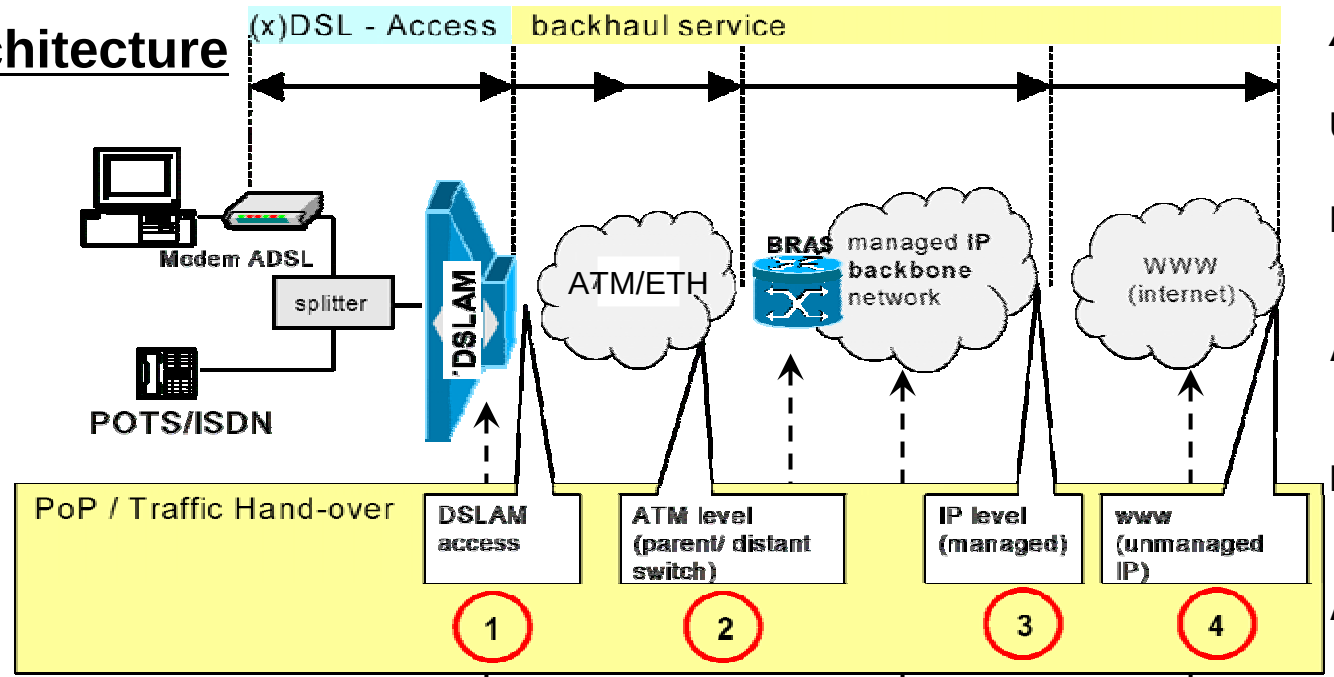
- **Centralized or fully distributed or hybrid architectures**
- **Cost effective small-scale to large-scale (sparse to dense radio coverage and capacity) deployments**
- **Urban, suburban and rural radio propagation environments shall be accommodated**
- **Licensed and/or licensed exempt frequency bands**
- **Hierarchical, non-hierarchical or flat access topologies**
- **Co-existence of fixed, nomadic, portable and mobile usage models**

The challenge: Come up with an architecture framework that enables vendor-interoperability without sacrificing implementation flexibility and avoiding over-specification

SIEMENS

WiMAX Architecture is aligned to DSL

DSL Architecture



Abbreviations:

UE
User Equipment

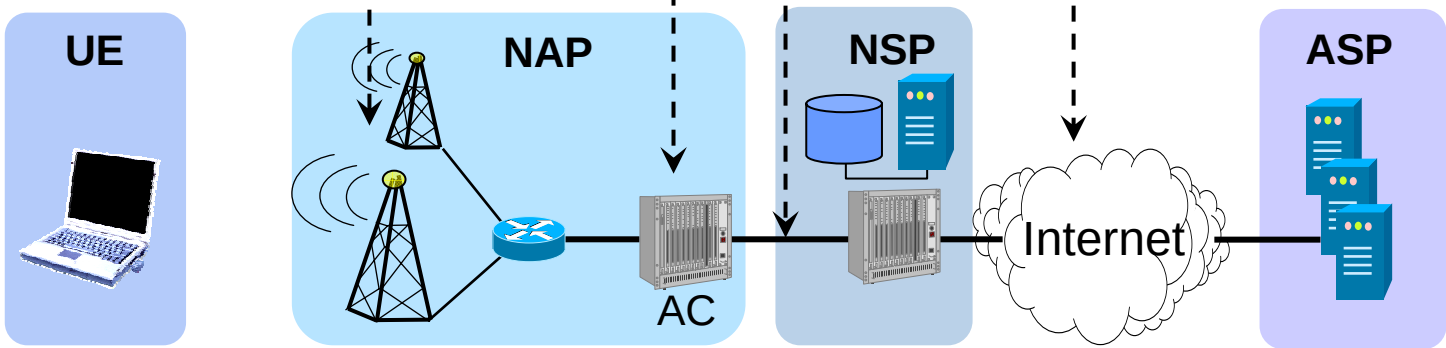
NAP
Network Access Provider

AC
Access Concentrator

NSP
Network Service Provider

ASP
Application Service Provider

WiMAX Architecture



SIEMENS

Network Operator Relationships

Network Access Provider (NAP)

- A business entity that provides WiMAX radio access infrastructure to one or more WiMAX Network Service Providers (NSPs). A NAP implements this infrastructure using one or more Access Service Networks (ASN)

Network Service Provider (NSP)

- A business entity that provides IP connectivity and WiMAX services to WiMAX subscribers compliant with the Service Level Agreement it establishes with WiMAX subscribers. To provide these services, an NSP establishes contractual agreements with one or more NAPs.
- An NSP may also establish roaming agreements with other NSPs and contractual agreements with third-party application providers (e.g. ASP or ISPs) for providing WiMAX services to subscribers.

ASP (Application Service Provider)

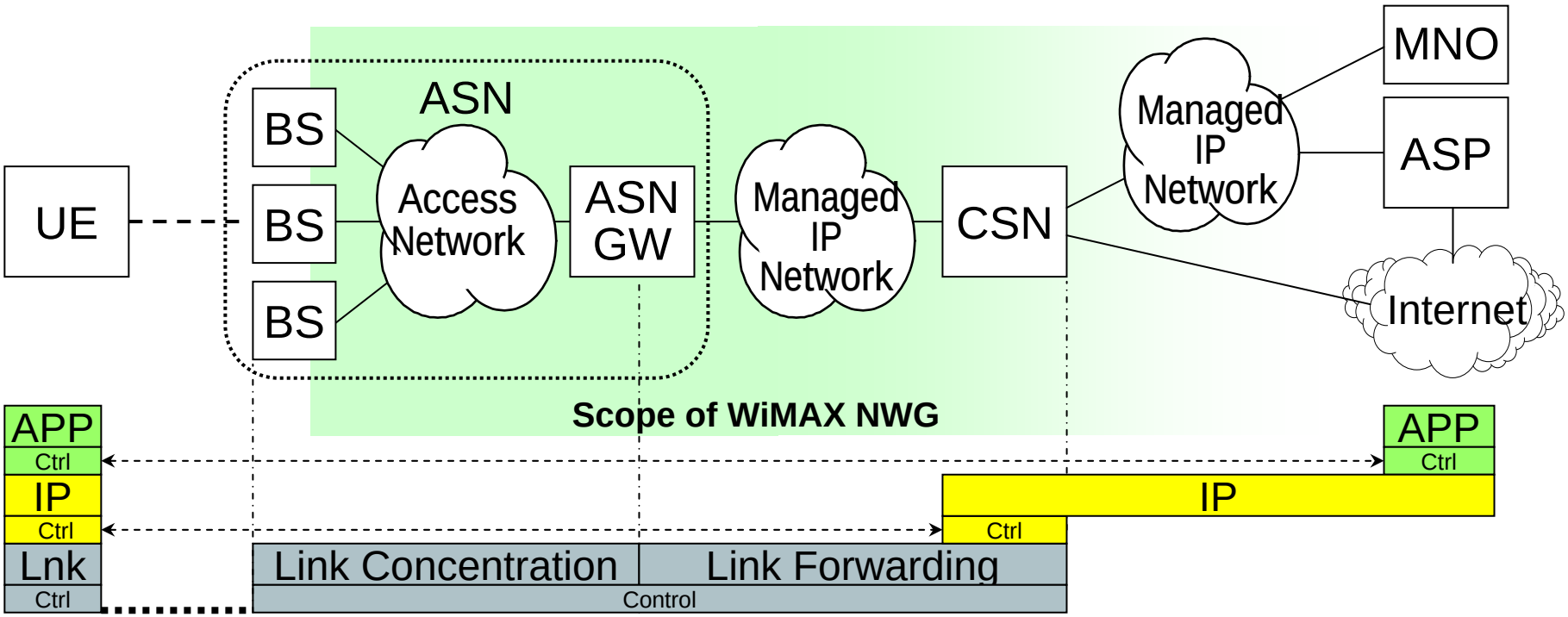
- Provides value added services, Layer 3+ (e.g. IMS, corporate access, ...)
- Provides and manages applications on top of IP

SIEMENS

WiMAX Network Architecture (logical view)

For comparison: ***Equivalent functions in a 3G network***

NodeB RNC, SGSN GGSN IMS

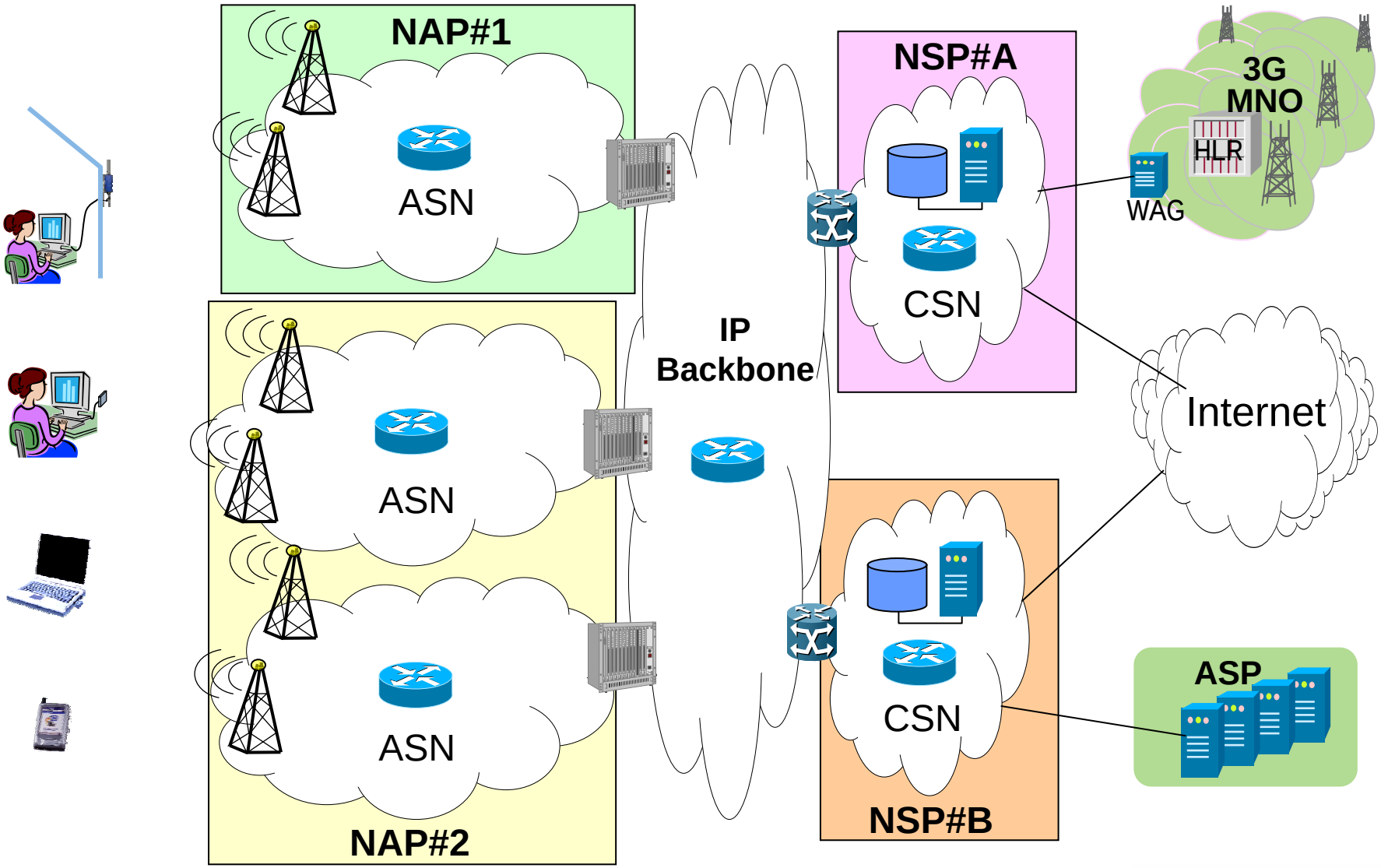


All kind of wide-area IP (access) networks are following the same structure/layers

- **Plain link-layer infrastructure for concentrating traffic of individual users (most economic)**
- **An entity providing an IP address to the UE for access to IP based applications/services**
- **Applications being agnostic to the particular infrastructure based on plain IP connectivity**

SIEMENS

WiMAX Network Architecture w/ NAP sharing

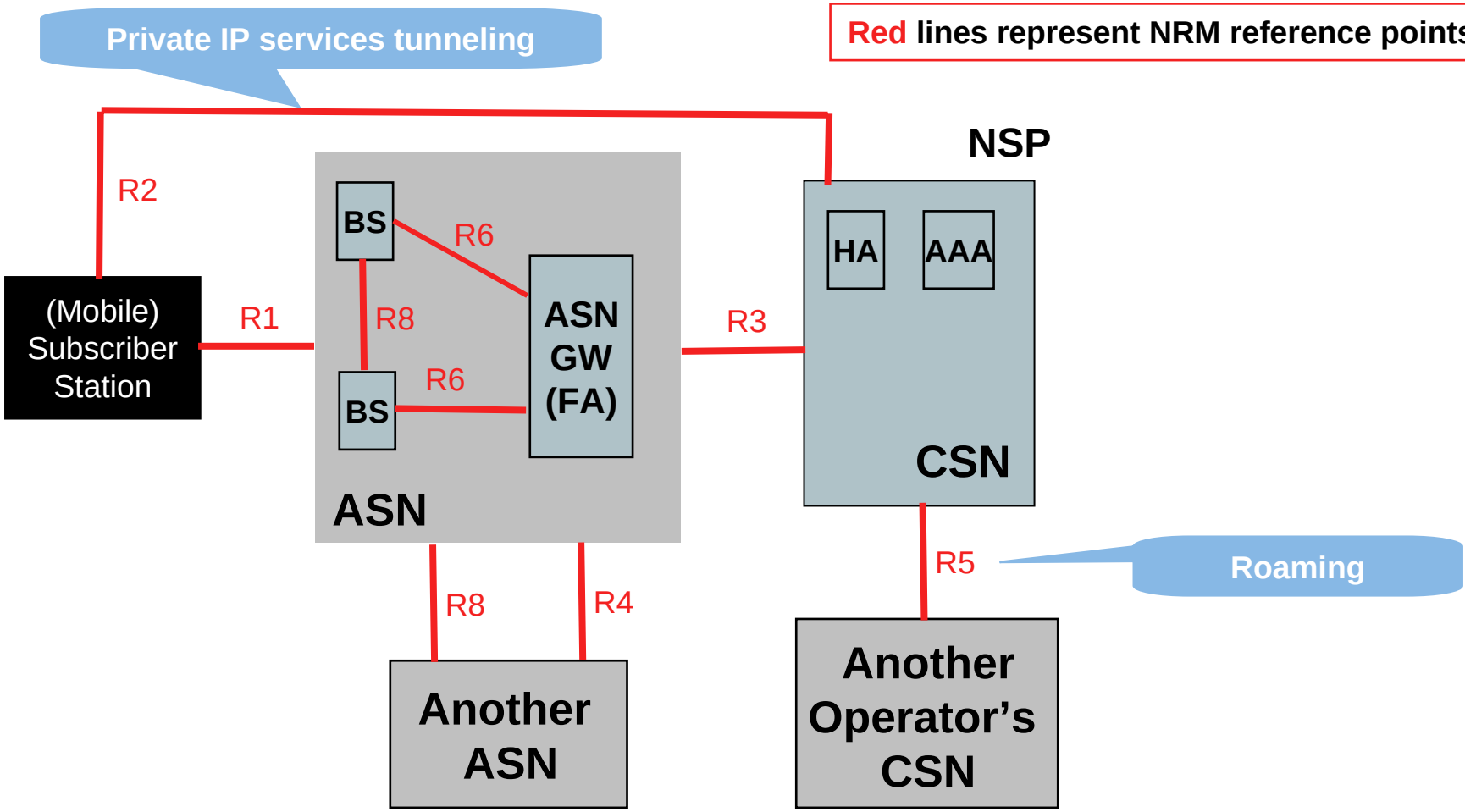


SIEMENS

WiMAX Network Reference Model

SIEMENS

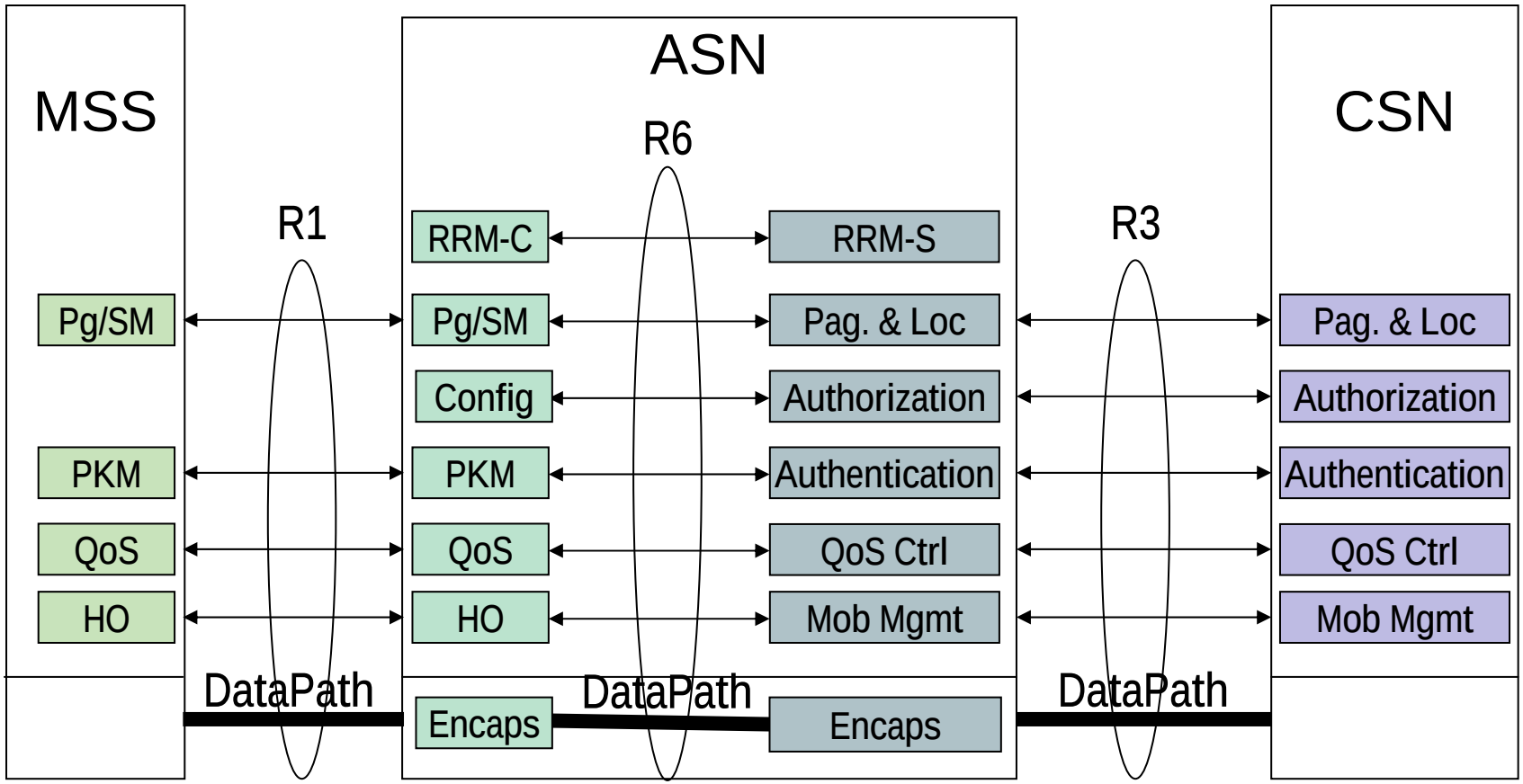
NWG's Network Reference Model (NRM)



NRM can be decomposed into a number of WiMAX access topological variants: Flat/Distributed, Hierarchical/Centralized, Decomposed versus Integrated BS …

SIEMENS

The network reference model can be sliced up
(R1, R3, R6 Illustrated)



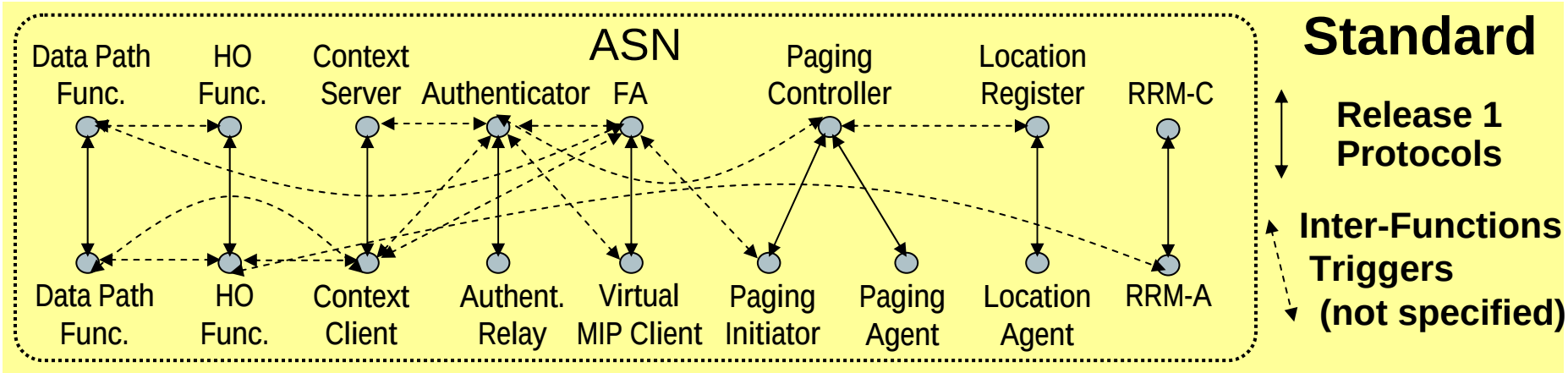
SIEMENS

Points to note about Reference Model!

- 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 specific physical entities are introduced ala SGSN, PDSN from the 3G world
- No single physical ASN or CSN topology is mandated – allowing room for vendor / operator differentiation

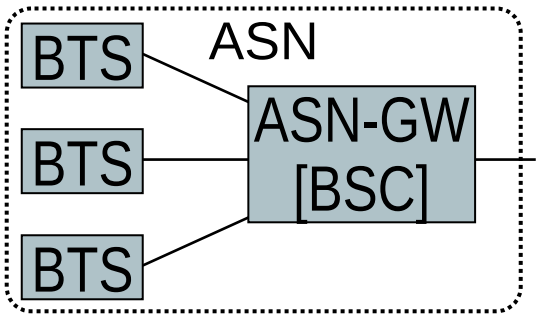
SIEMENS

Mapping functions to ASN Profiles



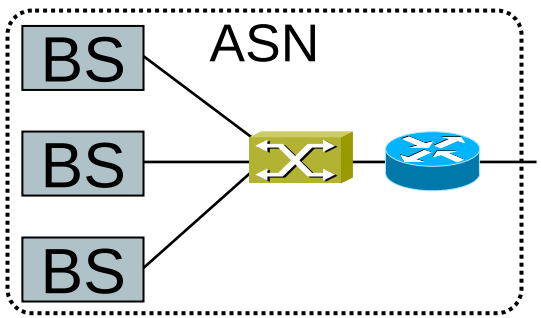
Profiles under discussion:

A



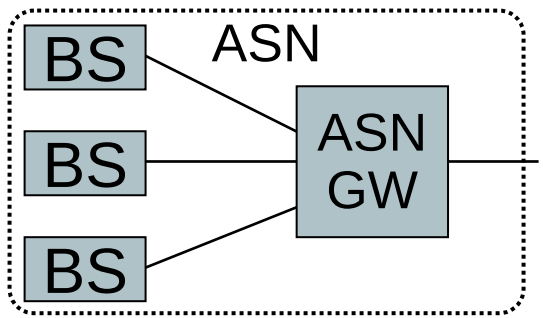
- PHY and partly MAC in BTS
- Handover-Ctrl (RRM) in ASN-GW
- Routing and AAA/Pg in ASN-GW

B



- nearly all ASN functions in BS
- BS anchored by standard router
- Inter BS control over Ethernet

C



- All radio-specific functions in BS
- Handover-Ctrl (RRM) in BS
- Routing and AAA/Pg in ASN-GW

SIEMENS

CSN Functional Decomposition

- **Connectivity to Internet, ASP and other PLMNs and Corporate Networks.**
- **User, equipment and services authentication, authorization and accounting (AAA).**
  - (Home) NSP distributes such user/equipment profile to the NAP directly or using Visited NSP (selected by the subscriber).
- **Roaming between NSPs**
- **IP address management (based on PoA management)**
- **Location management between ASNs**
- **Mobility and roaming between ASNs**
  - including connectivity and transport between multiple ASN coverage zones (subject to hierarchal structure).
- **Policy & QoS management based on the SLA/contract with the user.**

SIEMENS

Base Station Functional Decomposition

- **802.16 interface handling (e.g. PHY, MAC, CS, Scheduler) and processes as handover, power control and network entry.**
- **QoS PEP for traffic via air interface**
- **Micro Mobility HO triggering for mobility tunnel establishment**
- **Radio Resource Management Update**
- **MSS Activity Status update (Active, Idle)**
- **Supporting tunneling protocol toward ASN GW EP**
- **Traffic classification**
- **DHCP Proxy**
- **Key Management**
  - TEC/KEK Generation and delivery to the BS/MSS
- **Session Management (RSVP proxy)**
- **Managing Multicast Group association (IGMP proxy)**

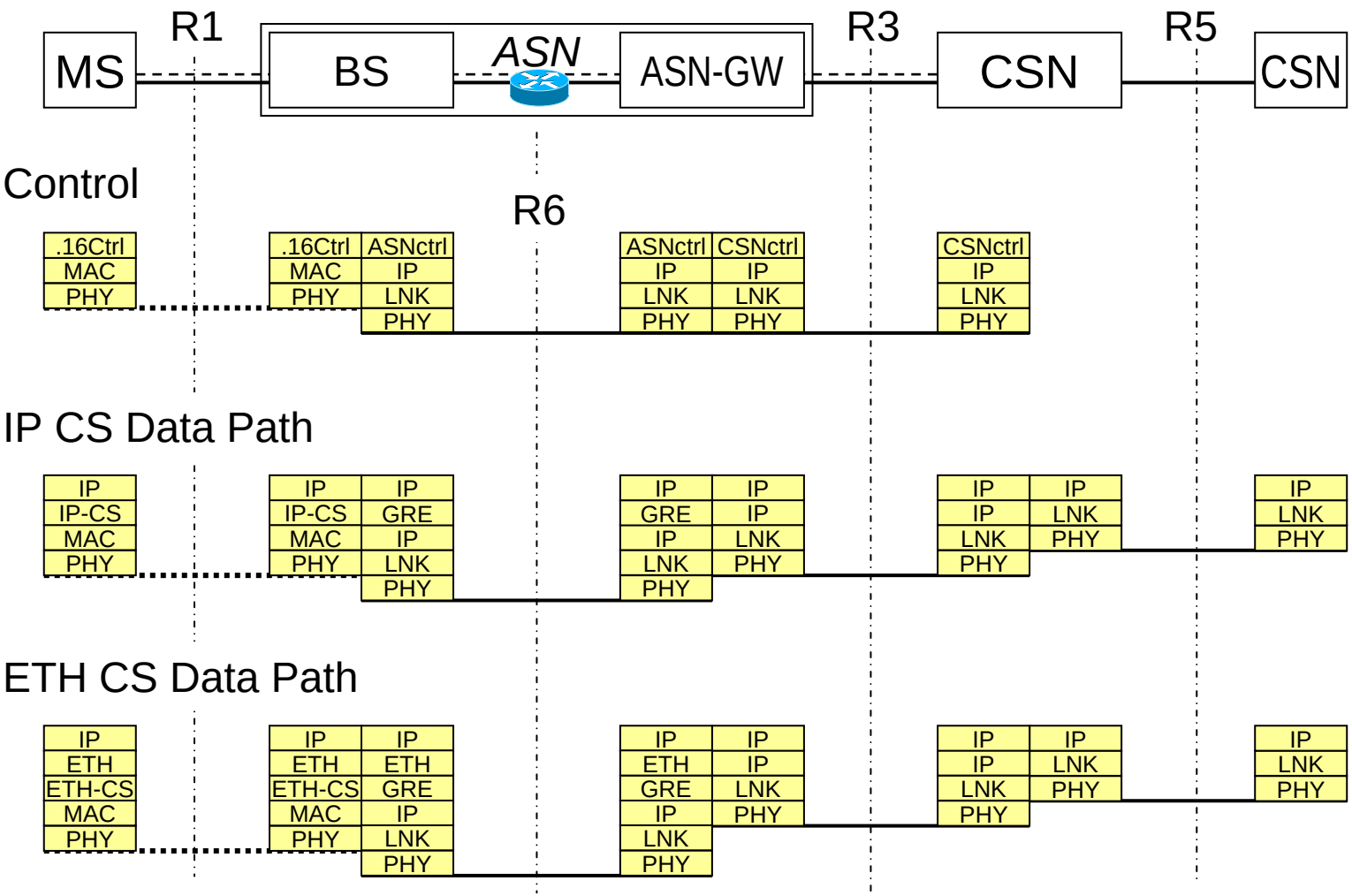
SIEMENS

ASN GW Decomposition

- **Intra ASN Location Management & Paging**
- **Network Session/Mobility Management (server)**
- **Regional Radio Resource Management & Admission control**
- **ASN Temporary Cashing subscriber profile and encryption keys (ASN like-VLR)**
- **AAA Client/Proxy**
  - delivery Radius/Diameter messaging to selected CSN AAA
- **Mobility Tunneling establishment and management with BSs**
- **Session/mobility management (client)**
- **QoS and Policy Enforcement**
- **Foreign Agent (FA) (with Proxy MIP)**
- **Routing to selected CSN**

SIEMENS

Protocol Layering

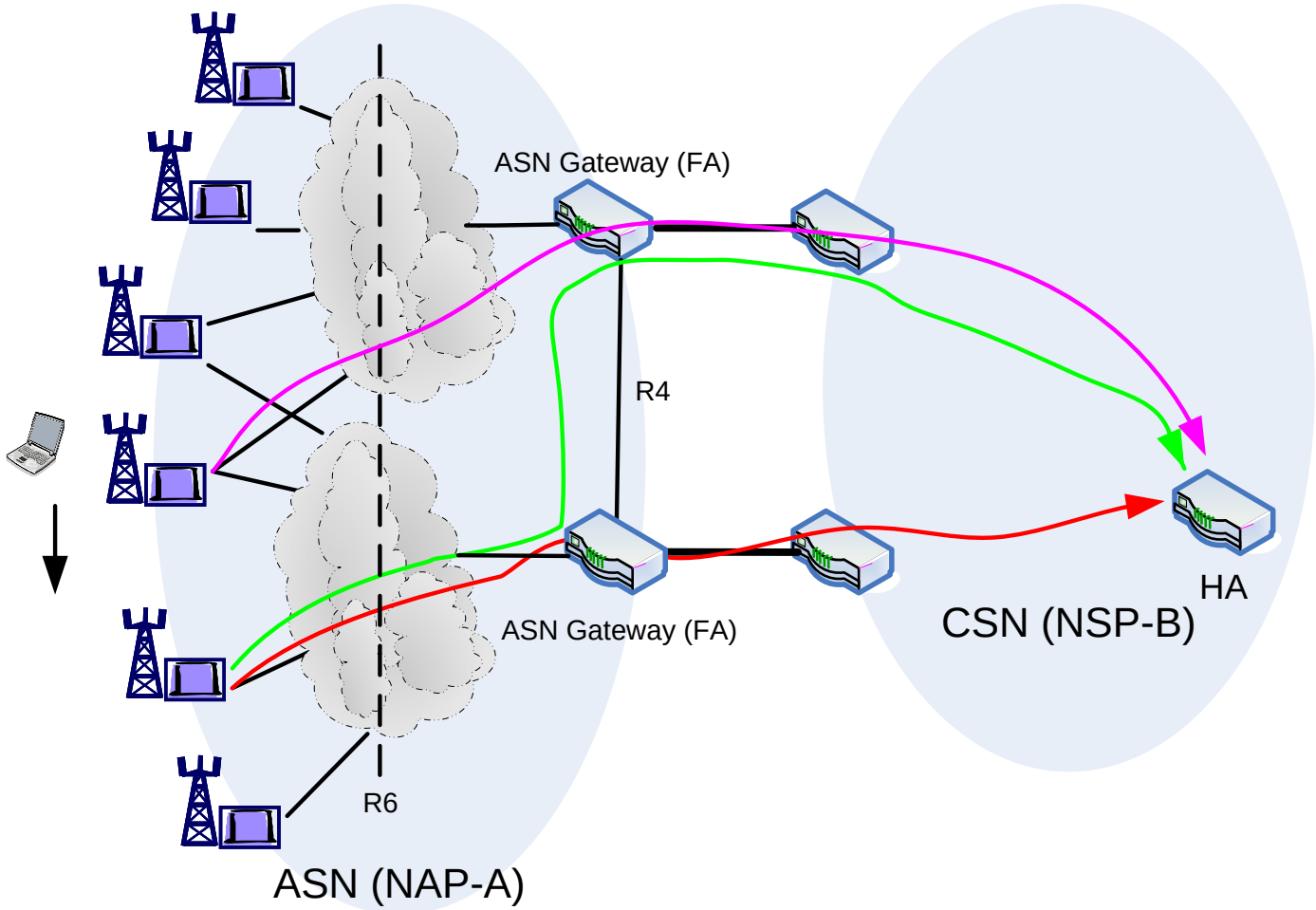


SIEMENS

WiMAX Mobility Management

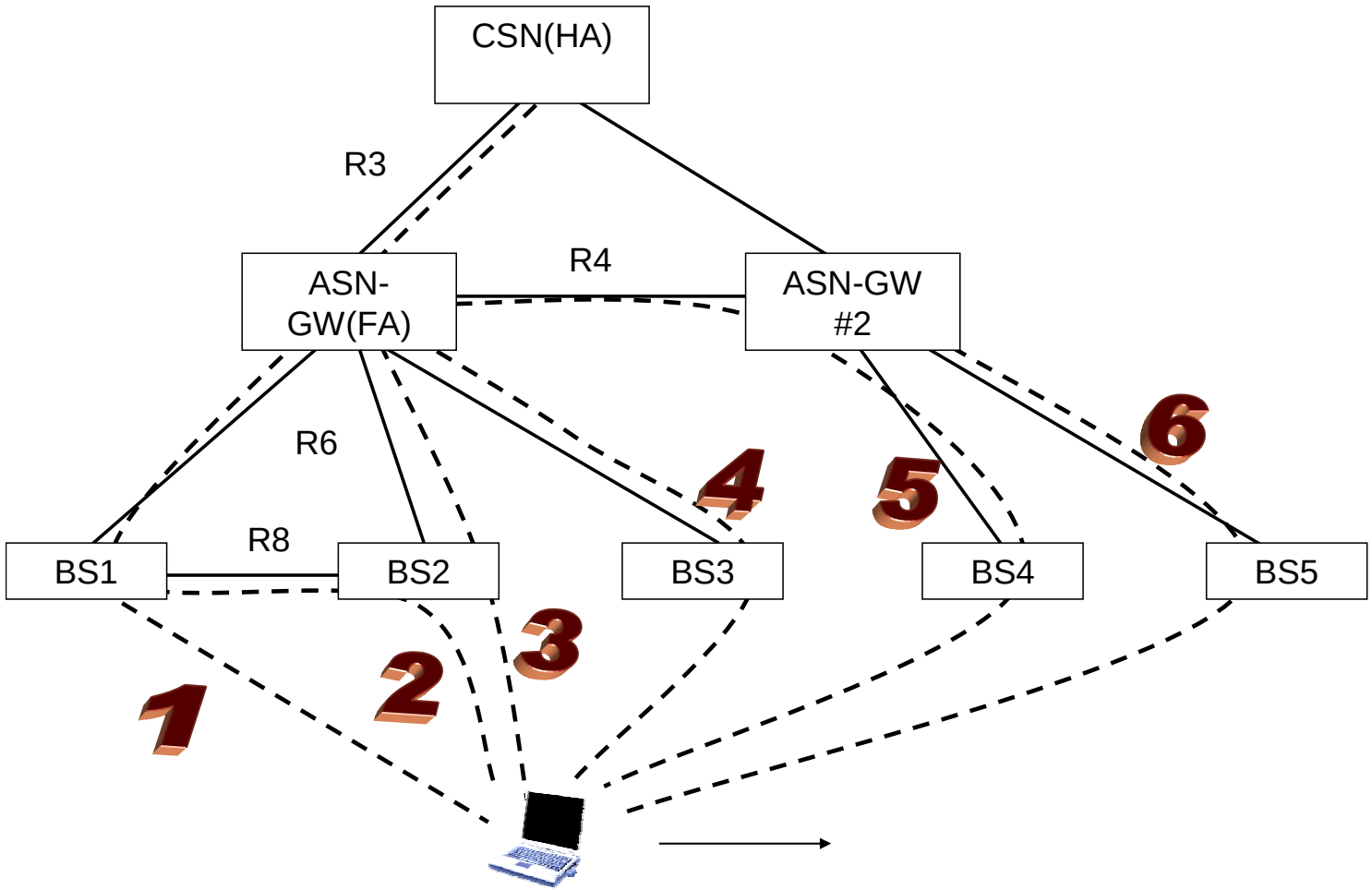
SIEMENS

Mobility Scope



SIEMENS

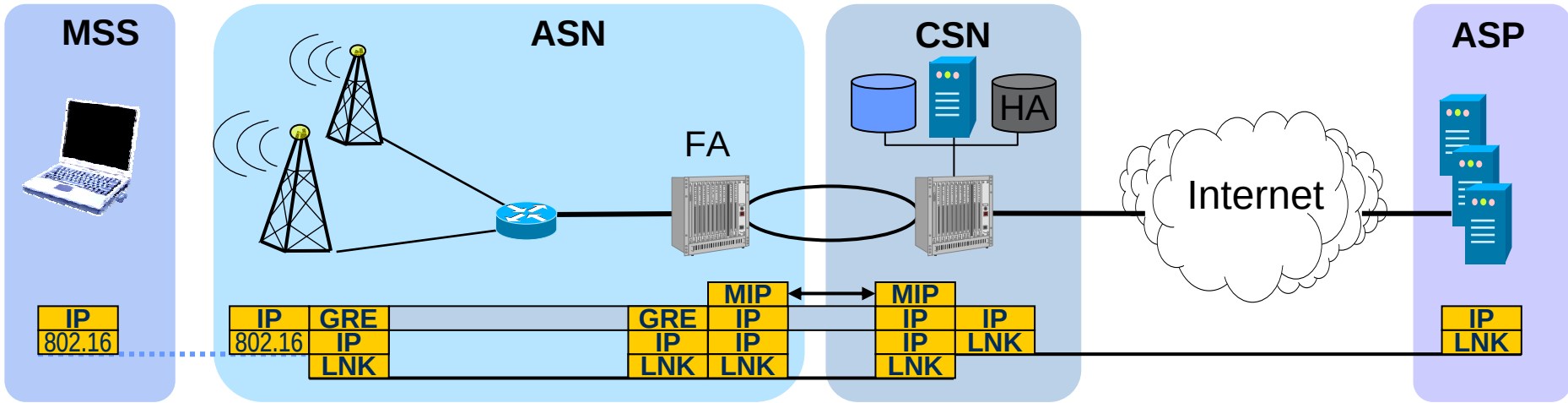
WiMAX NWG Handover scenarios



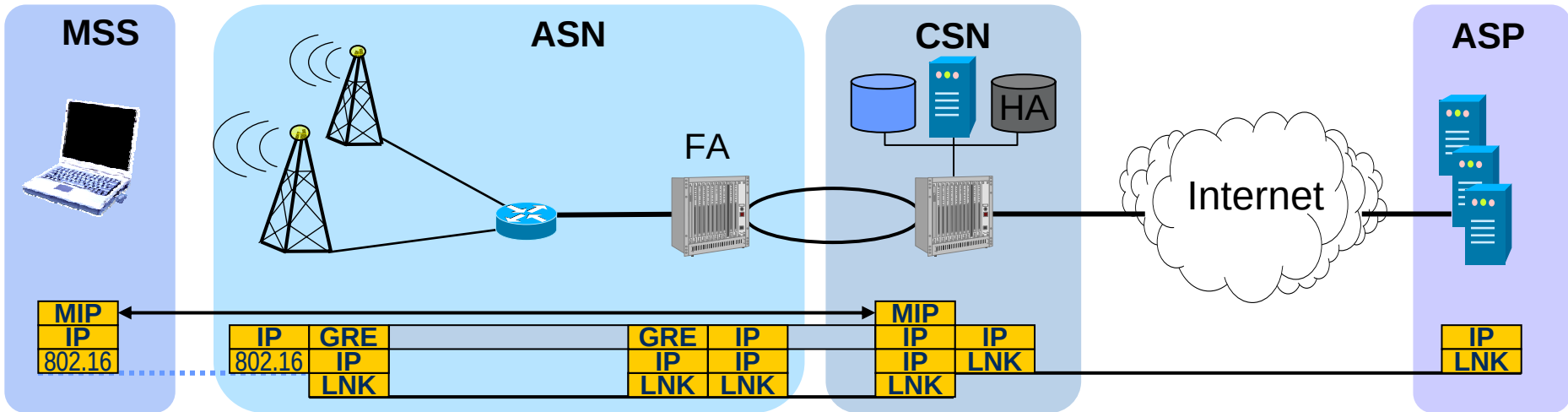
SIEMENS

Proxy-MIP/Client-MIP Mobility

Proxy-MIP: MIP Client resides in ASN-GW



Client-MIP: MIP Client resides in MSS

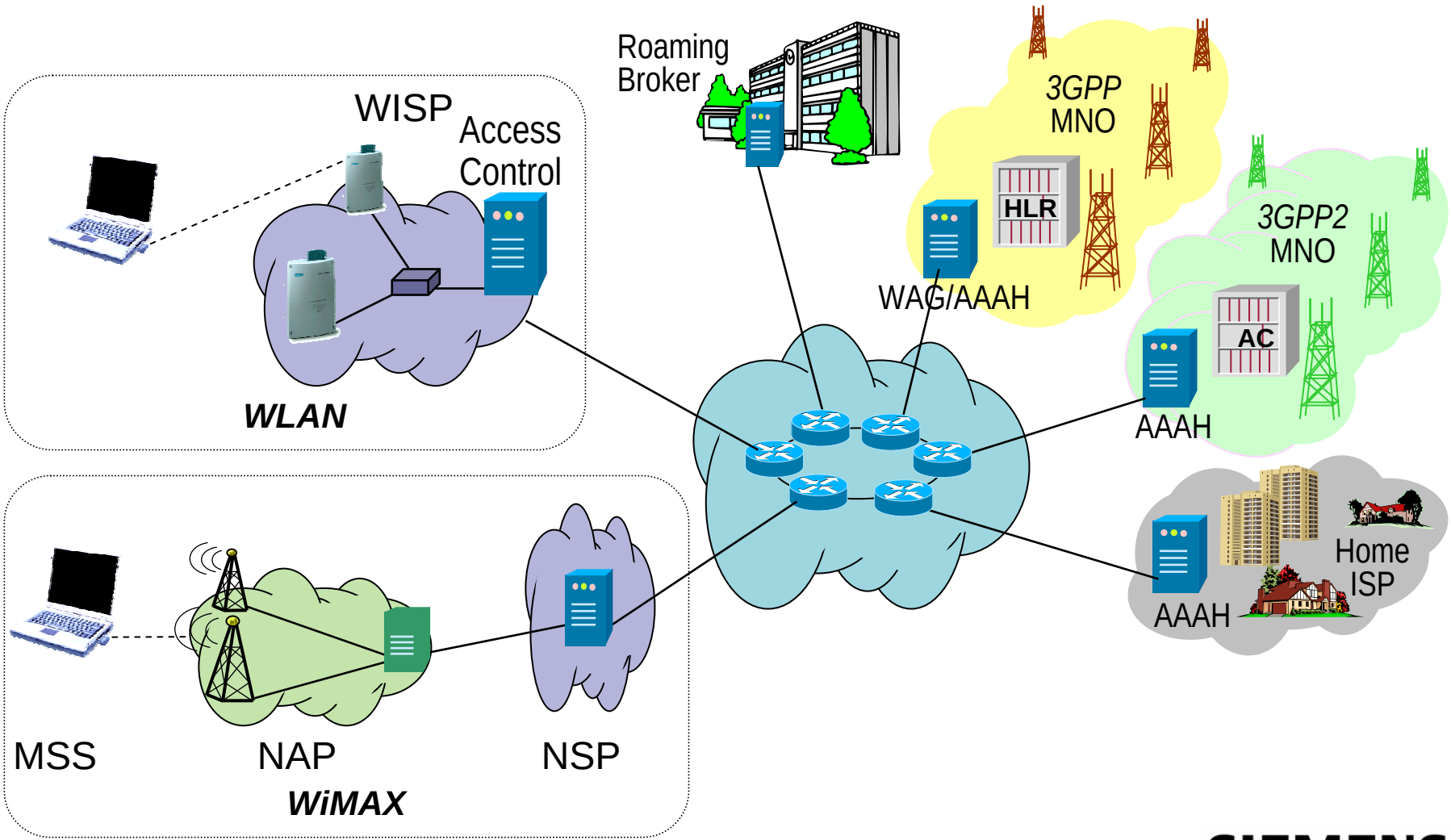


SIEMENS

WiMAX Interworking with 3G

SIEMENS

WiMAX Interworking is like WLAN Interworking

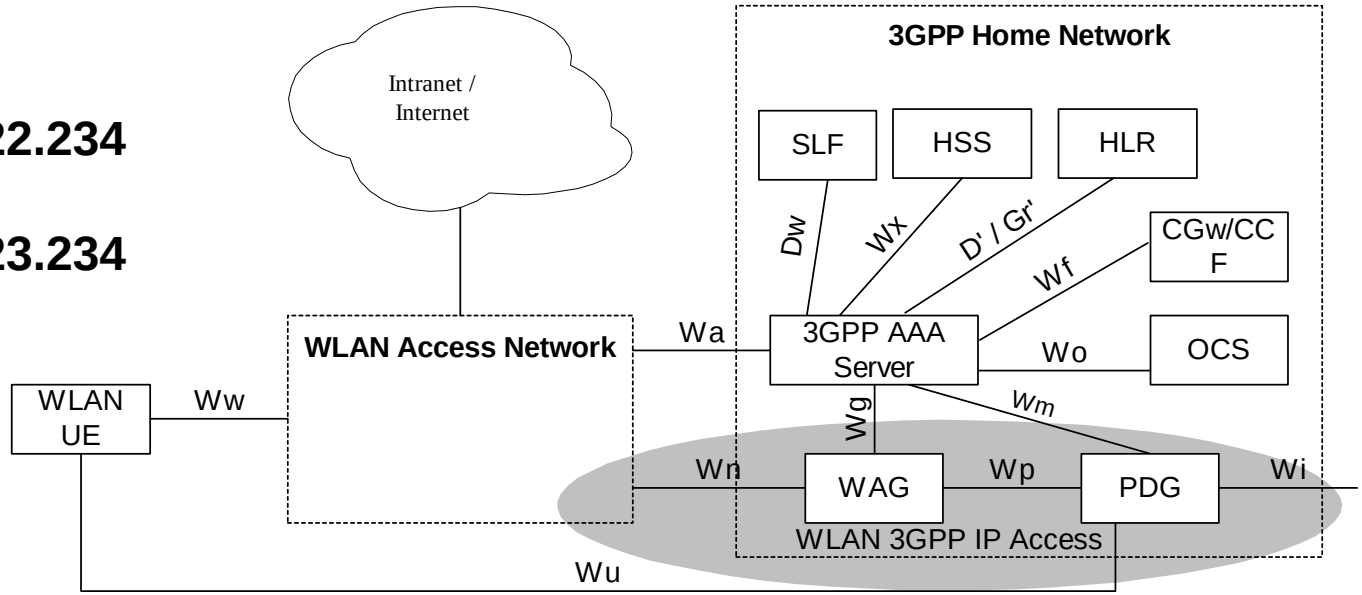


SIEMENS

3GPP WLAN Interworking Scenarios

Stage 1:
- **3GPP TS 22.234**

Stage 2:
- **3GPP TS 23.234**



WLAN access
- **Scenario 1: Common Billing and Customer Care**
- **Scenario 2: 3GPP system based Access Control and Charging**

AAA Roaming

Access to 3G services over WLAN
- **Scenario 3: Access to 3GPP PS based services**
- **Scenario 4: Service Continuity**

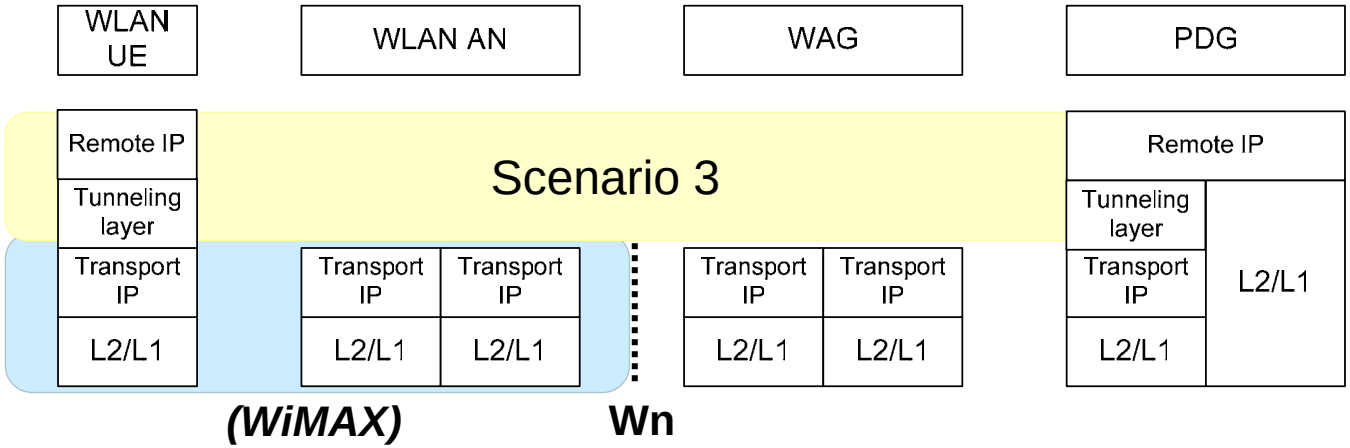
IPsec VPN
- **Scenario 5: Seamless services**

tbd
- **Scenario 6: Access to 3GPP CS Services**

(UMA)

SIEMENS

3GPP Scenario 3



Scenario 3 defines an E2E VPN solution based on IP connectivity

Scenario 3 may be combined with scenario 2 (dual authentication)

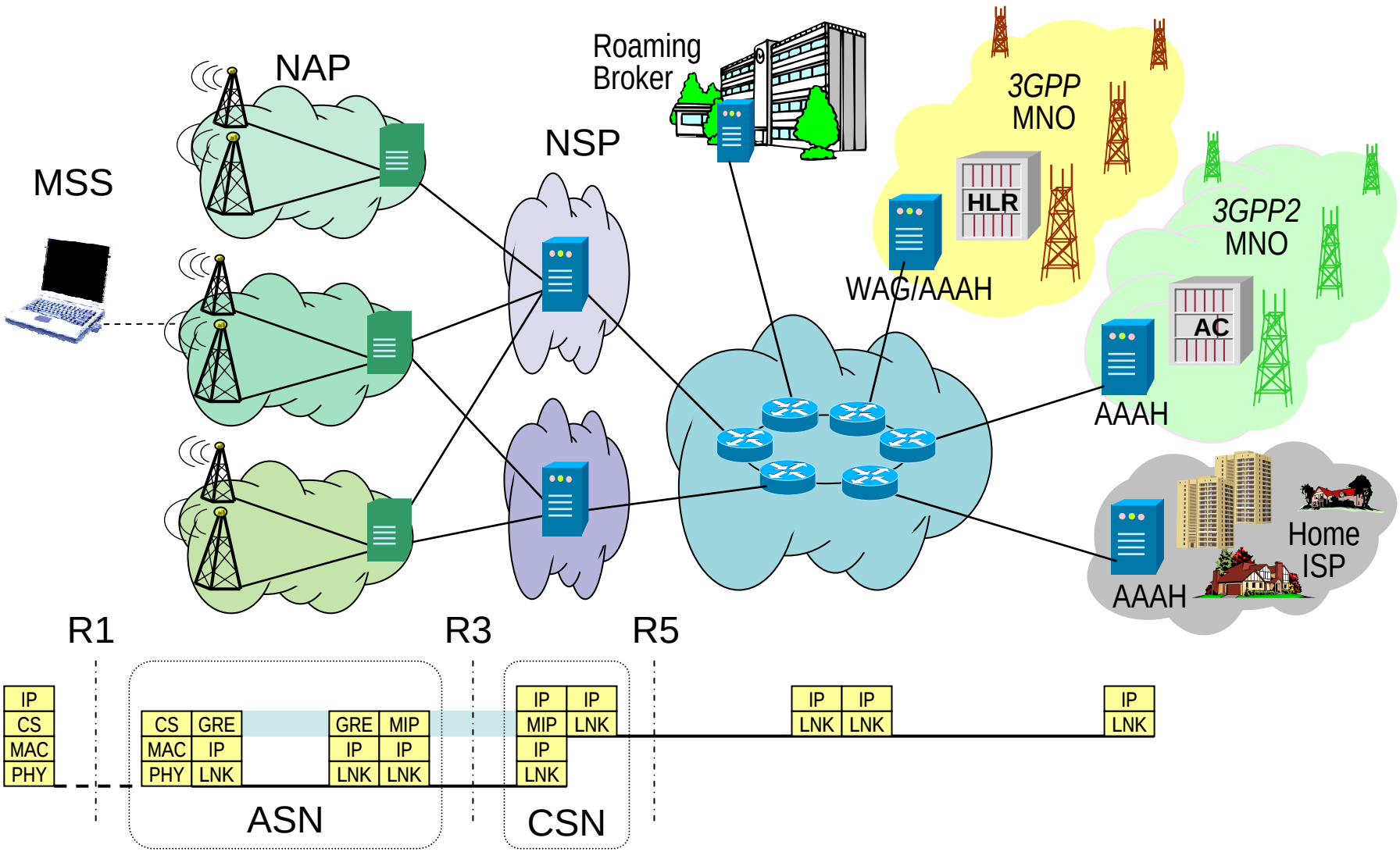
Wn: reference point between the WLAN Access Network and WAG

- **The specific method to implement this interface is subject to local agreement between the WLAN AN and the PLMN**

Basics of stage 3 clarified in SA3 (EAP-SIM/AKA over IKEv2)

SIEMENS

WiMAX Interworking model



SIEMENS

Open issue:
Indoor penetration

SIEMENS

FWA is remaining important, even when going full mobility

How far does it go? It depends where your terminal is!

Consider a hypothetical broadband (1Mb/s) wireless network

3 Sector base station at 25m to:

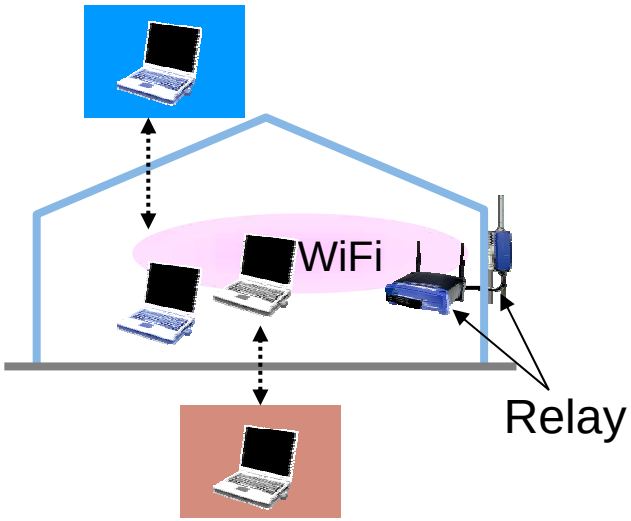
	Gain	Height	Building loss	Range	Relative site count
Rooftop – LOS	10 dBi	8 m	0 dB	> 30km	
Rooftop NLOS	10 dBi	8 m	0 dB	6.2 km	1
Terminal / Gateway in upstairs window	3 dBi	5 m	0 dB	1.8 km	12
Outdoor PCcard	0 dBi	1.5 m	0 dB	780 m	60
Indoor PCcard - Suburban	0 dBi	1.5 m	10 dB	410 m	230
Indoor PCcard - Urban	0 dBi	1.5 m	20 dB	210 m	800

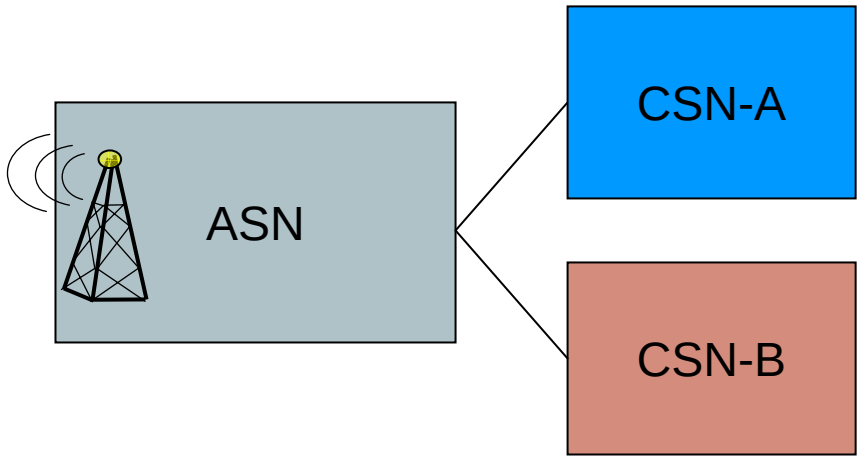
All figures except LOS based on COST231-Hata model with 10dB shadow margin and no cable losses. System operates at 2GHz with 1Mb/s from 24dBm EIRP terminal TX, 3dB Eb/No, 5dB NF RX. BS antenna = 18dBi

Page 1

_GROUP R&D

WiMAX relaying issues





WiMAX-WiFi relays are solving the indoor penetration issues

- **Relays should work without any configuration (consumer market!)**
- **Relays may be concurrently used by several 'MSSs'**
  - 'MSSs' may belong to different NSPs
    - NSPs may use overlapping (private) IP address space
- **The same subscription should be usable behind a WiMAX-WiFi relay**
  - Providing the prerequisites for QoS-enabled secure WLAN access (VoIP!)

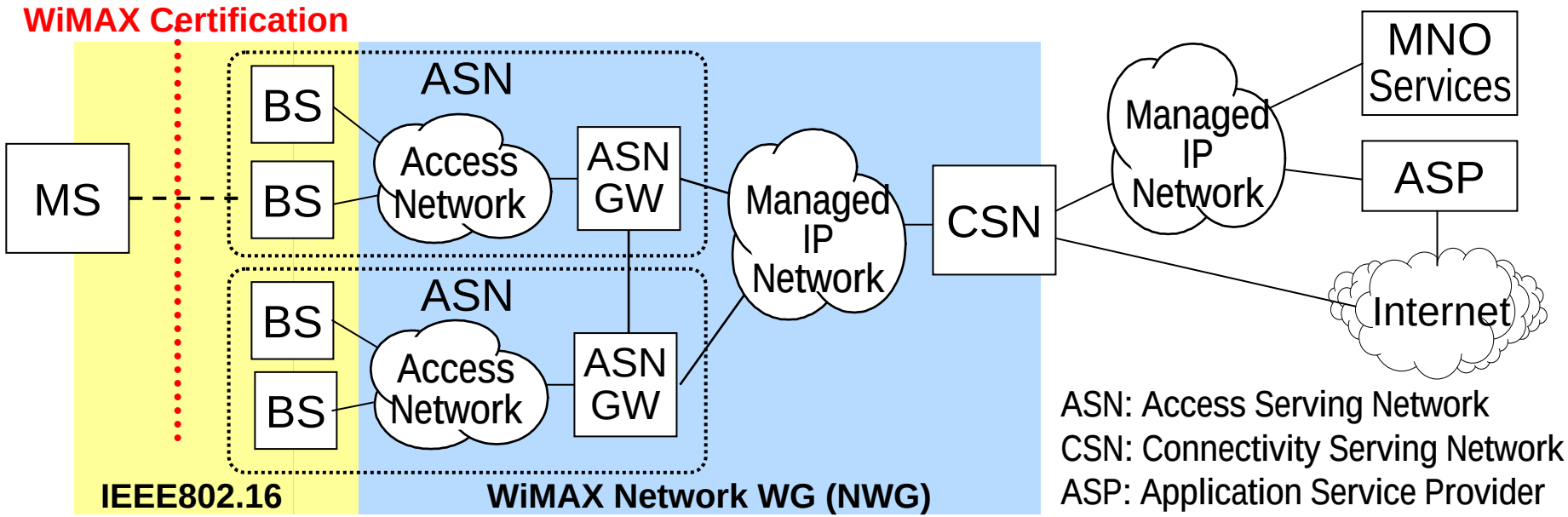
SIEMENS

Conclusion

SIEMENS

Mobile WiMAX Networking

For comparison: Equivalent functions in a 3G network
UE NodeB RNC, SGSN GGSN, HSS IMS



- **IEEE802.16 takes care of PHY and MAC of radio interface**
  - 802.16e extends MAC & PHY for mobility *Dec. '05*
- **WiMAX provides profiles and certification for .16e** *End '05/Mid '06*
- **WiMAX NWG specifies access network architecture** *Rel 1: Mid '06*
  - based on IETF protocols, 'merged' 3GPP2/DSL/(3GPP) architecture

SIEMENS

The End

Thank you for your attention!

SIEMENS