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Wide Area Wireless Ethernet

Providing Ethernet based services over Mobile WiMAX

Max Riegel

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Overview

- Motivation

- IEEE802.16 and WiMAX

- The Mobile WiMAX Network Architecture
  - WiMAX Network Reference Model
  - Mobility support

- The Data Path

- Ethernet Services
  - Metro Ethernet Services over WiMAX
  - Interworking with DSL over WiMAX

- Relays
  - Multiple Hosts Support in WiMAX

- Conclusion

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Why, Max?

'WiMAX' is addressing a new segment in the telecommunication market

	"Integrated Services Digital Network"	"Digital Subscriber Line"
fixed	POTS, ISDN (B-ISDN, ATM)	xDSL, Cable
mobile	DECT GSM, UMTS (WCDMA, HSDPA)	Wi-Fi 'WiMAX'

- End-to-end QoS
- Hard real-time (voice) Defined traffic classes
- End-to-end service delivery
  - Voice, SMS, Gaming, Infotainment
- Precise accounting, charging and billing

- Best effort, DIFFSERV enabled
- Interactive (http, mail) Streaming, downloads
- Access to the plain Internet
  - Common web applications, email
- Usage classes, flat-rate

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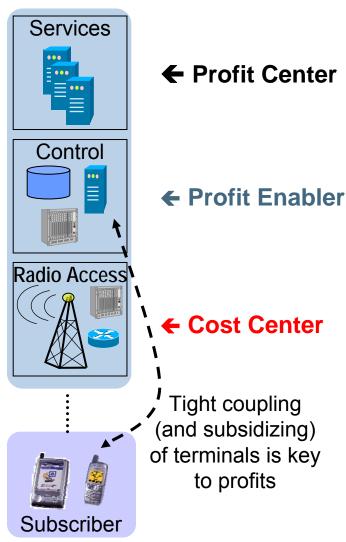 Mobile WiMAX4BWA2007/ Max Riegel / 2007-09-13

UMTS is optimized for Integrated Services

- UMTS/HSDPA does not scale well for high average bitrates
  - Investment costs of WiMAX are lower above ~10 kbit/s per subscriber
- With similar costs for basestations, HSDPA is burdened by its UMTS siblings in the access and core network
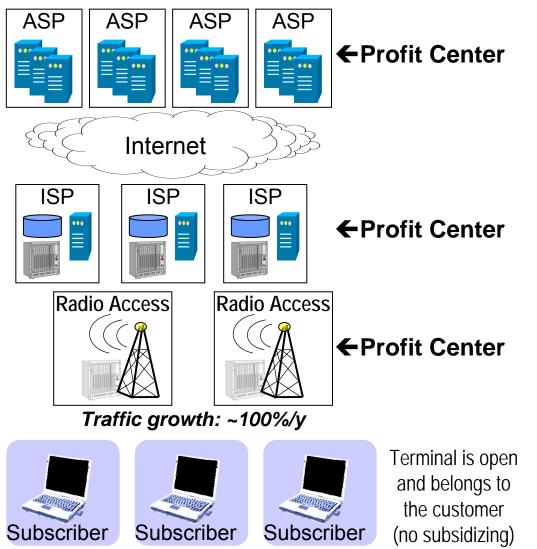 - The WiMAX network is legacy-free and is optimized for high bandwidth

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The Mobile Network Operator Value Chain

Services

← **Profit Center**

Control

← **Profit Enabler**

Radio Access

← **Cost Center**

Tight coupling (and subsidizing) of terminals is key to profits

Subscriber

- Commercial operations tend to focus onto their profits

- In a world of saturated markets and high competition the increase of the customer base is hardly a way to increase profits.

- Keys to higher profits are increased use of existing services or intro-duction of new services to the established customer base (ARPU).

- Transfer of bits to the subscriber is just adding to costs and should be kept minimal (SMS!)

  - results in traffic growth of ~7%/year

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The Broadband Operator Value Pattern

| ASP | ASP | ASP | ASP |

← **Profit Center**

Internet

| ISP | ISP | ISP |

← **Profit Center**

Radio Access   Radio Access

← **Profit Center**

Traffic growth: ~100%/y

Subscriber   Subscriber   Subscriber

Terminal is open and belongs to the customer (no subsidizing)
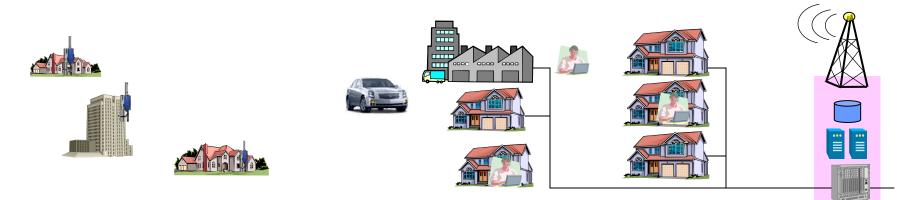
By allowing everybody to provide services, the Internet introduced a major change in the value creation of network operators.

Application service provision, connectivity service provision and access service provision have become independent businesses in a competitive market.

This led to the pervasive proliferation of services over broadband pipes.

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WiMAX deployment evolution

Today's broadband providers are tied to their wires

- serving consumers and enterprises inside their reach

A WiMAX access network allows to extend the DSL business serving customers without appropriate wires, and additionally also...
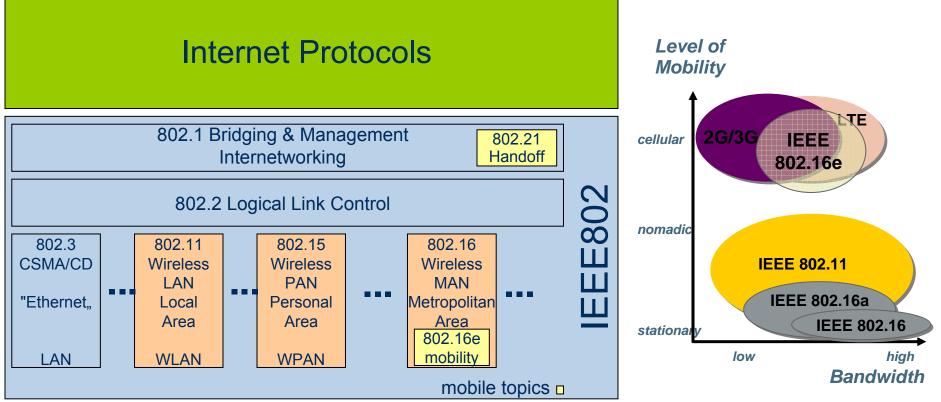
- addressing customers looking for a more easy-to-use solution,
- providing portable and mobile access

All together may be necessary for a successful business case!

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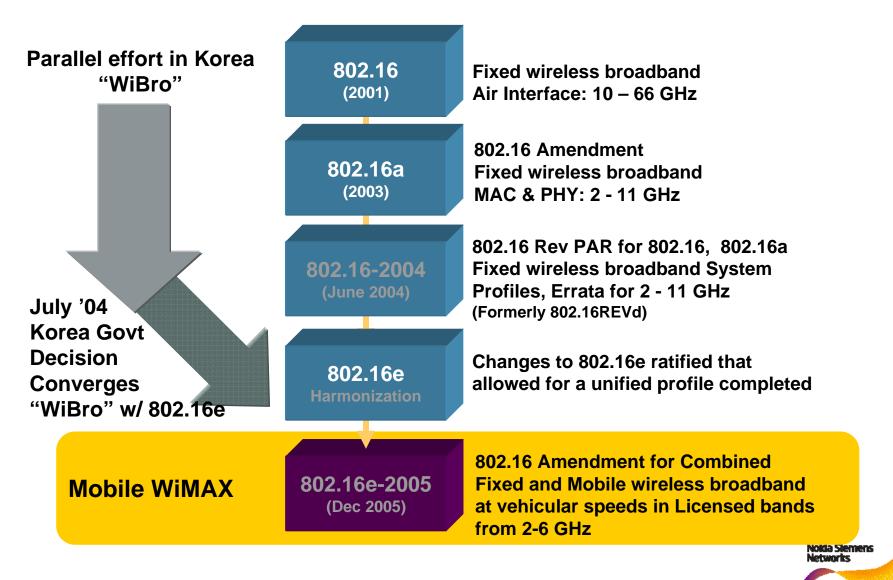# IEEE802.16 and WiMAX

Wireless Mobility in IEEE802

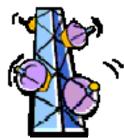IEEE802 provides specifications for Local and Metropolitan Networks
- Wireless topics: WPAN (802.15), WLAN (802.11), WMAN (802.16)
- IEEE802.16e provides cellular support including full mobility

IEEE802 has become the leading 'radio' standardization organization
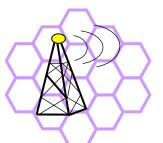- e.g. MMR (802.16j), Cognitive Radio (802.22)

The Evolution of IEEE802.16

Parallel effort in Korea "WiBro"

802.16
(2001)

Fixed wireless broadband
Air Interface: 10 – 66 GHz

802.16a
(2003)

802.16 Amendment
Fixed wireless broadband
MAC & PHY: 2 - 11 GHz

802.16-2004
(June 2004)

802.16 Rev PAR for 802.16, 802.16a
Fixed wireless broadband System
Profiles, Errata for 2 - 11 GHz
(Formerly 802.16REVd)

**July '04
Korea Govt
Decision
Converges
"WiBro" w/ 802.16e**

802.16e
Harmonization

Changes to 802.16e ratified that
allowed for a unified profile completed

Mobile WiMAX

802.16e-2005
(Dec 2005)

802.16 Amendment for Combined
Fixed and Mobile wireless broadband
at vehicular speeds in Licensed bands
from 2-6 GHz

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IEEE 802.16: 'One wireless standard fits all'

	Feeding	FWA	Cellular
Completed	December 2001	January 2003	December '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	2-5 km	7 to 10 km, up to 50 km	1-5 km

     Mobile WiMAX4BWA2007/ Max Riegel / 2007-09-13
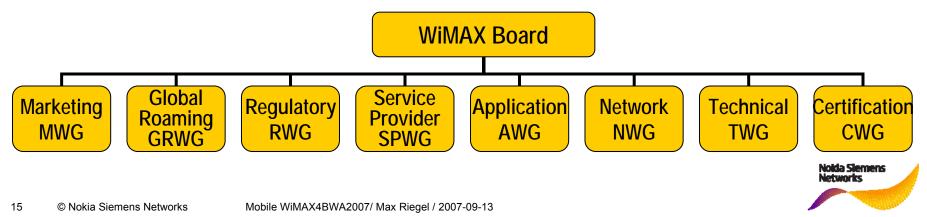
WiMAX and IEEE 802.16

- WiMAX is a subset of IEEE 802.16
  - No new features can be added
- Mandatory features in 802.16 are mandatory in WiMAX, if included
- Optional features in 802.16 may be optional, mandatory or not included

Fixed WiMAX – 256 OFDM

IEEE 802.16 World

WiBro

Mobile WiMAX - OFDMA

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WiMAX:
Worldwide Interoperability for Microwave Access

The WiMAX Forum promotes the deployment of broadband wireless access networks by supporting a global standard and certifying interoperability of products and technologies.

- Support IEEE 802.16 standard family

- Propose and promote access profiles for their IEEE 802.16 standard

- Certify interoperability levels both in the network (IIOT) and the radio interface (RCT/PCT/NCT)

- Achieve global acceptance

- Promote use of broadband wireless access overall

```
                          WiMAX Board
  ┌──────────┬──────────┬──────────┬──────────┬──────────┬──────────┬──────────┐
Marketing   Global   Regulatory  Service   Application  Network   Technical  Certification
  MWG      Roaming      RWG      Provider      AWG         NWG        TWG         CWG
            GRWG                   SPWG
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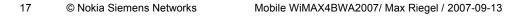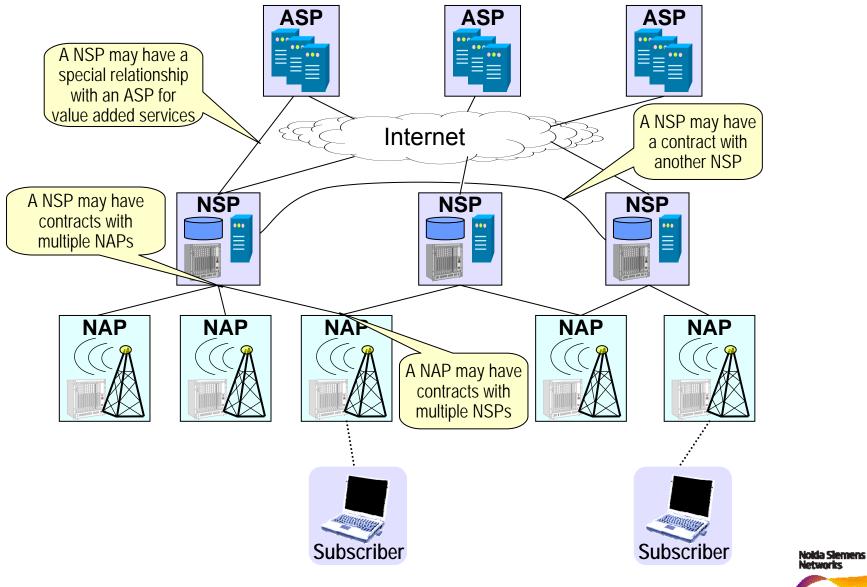
The Mobile WiMAX Network Architecture

A Wireless Access Network for the Internet

- Content is not tied to a particular Core but on the Internet
  - Split between Application Service Provider and Network Service Provider
- Often Access is operated as independent business
  - Network Access Provider does not like to deal with the consumer but concentrates on establishment and operation of its network infrastructure
  - Facilitates shared access network by multiple service providers, which is beneficial for economy of scale and ROI.
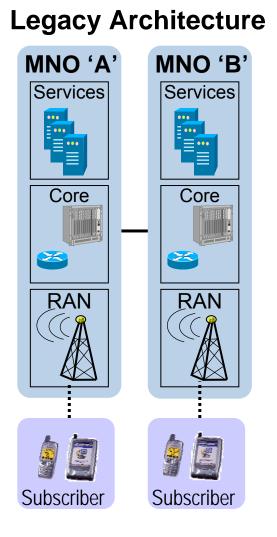
Network Operator Relationships in WiMAX

ASP **ASP** **ASP**

A NSP may have a special relationship with an ASP for value added services

Internet

A NSP may have a contract with another NSP

A NSP may have contracts with multiple NAPs

NSP **NSP** **NSP**

NAP **NAP** **NAP** **NAP** **NAP**

A NAP may have contracts with multiple NSPs

Subscriber

Subscriber

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Entities of the WiMAX Network Reference Model

- ## CSN: Connectivity Serving Network
  - Logical representation of the functions of a NSP, e.g.
    - Connectivity to the Internet, 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 ctrl.
    - L2 Session/mobility management
    - QoS and Policy Enforcement
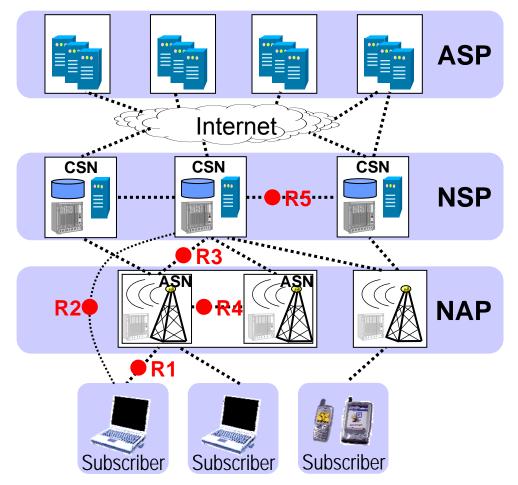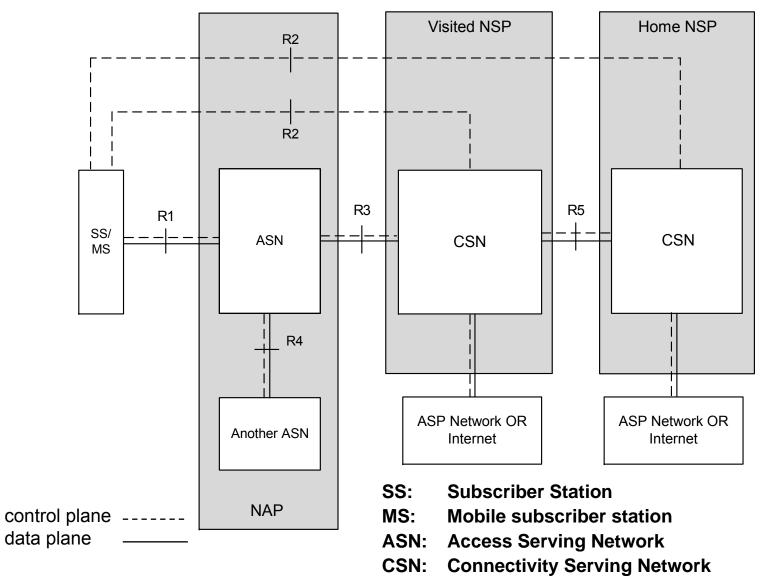   - Foreign Agent (FA)
    - Forwarding to selected CSN
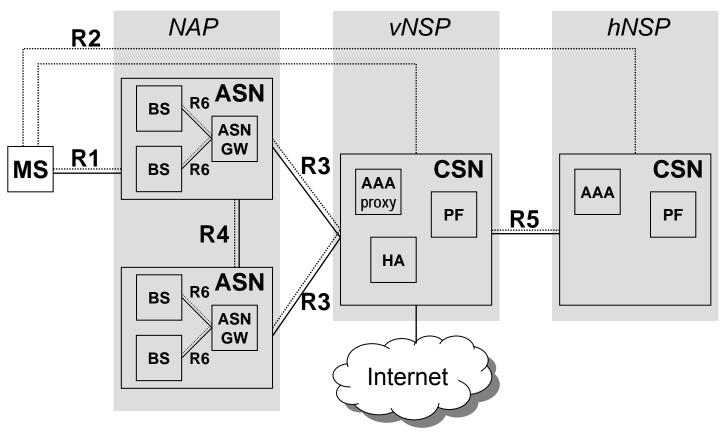
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Mobile Network Architectures

Legacy Architecture

Mobile WiMAX Network Architecture

Mobile WiMAX Network Reference Model (NRM)

SS: **Subscriber Station**
MS: **Mobile subscriber station**
ASN: **Access Serving Network**
CSN: **Connectivity Serving Network**

control plane
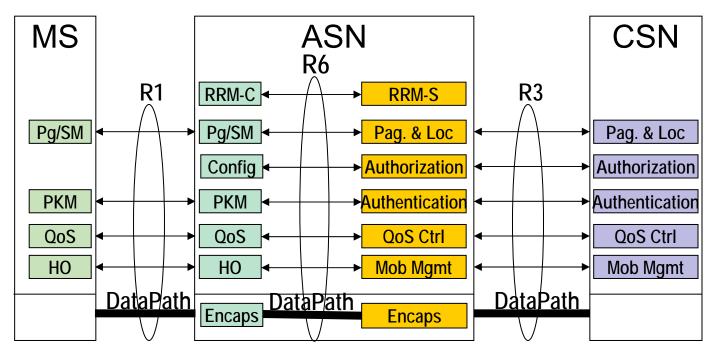data plane

WiMAX Network Reference Model (roaming case, HA in vNSP)

- The NRM defines also a logical decomposition inside the ASN (BS, ASN-GW)
  - Most implementations follow this logical structure

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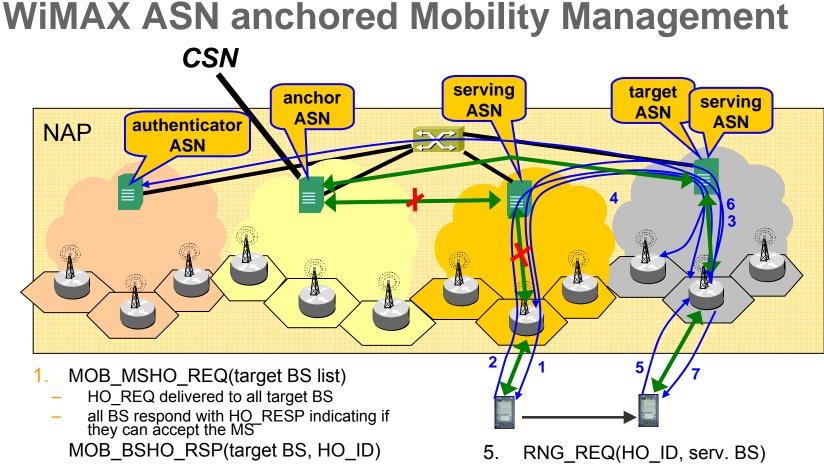
WiMAX Reference Points

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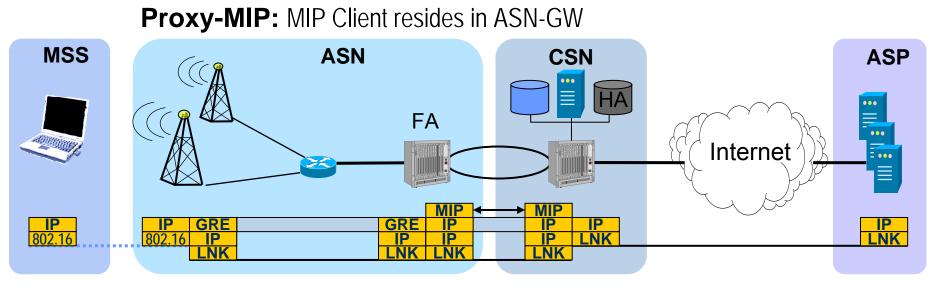 - If a particular protocol is present, it must conform to the WiMAX specification

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WiMAX ASN anchored Mobility Management

1. MOB_MSHO_REQ(target BS list)
   - HO_REQ delivered to all target BS
   - all BS respond with HO_RESP indicating if they can accept the MS
   MOB_BSHO_RSP(target BS, HO_ID)

2. MOB_HO_IND(target BS)
   - HO_Confirm delivered to the target BS

3. Retrieve Key
   - authenticator ID is part of MS context

4. Data path to anchor GW
   - anchor GW ID is part of MS context
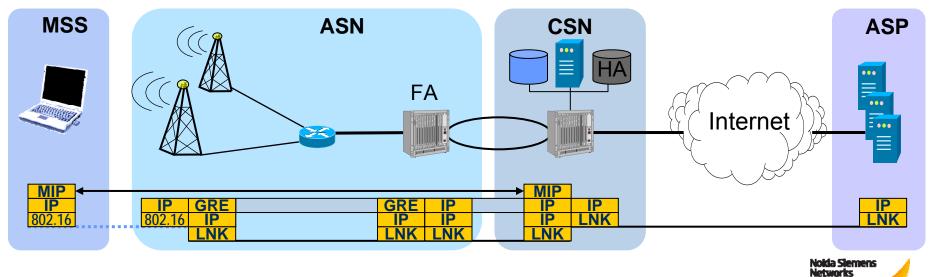
5. RNG_REQ(HO_ID, serv. BS)

6. HO_Complete

7. RNG_RSP(new CID to SF mapping)

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WiMAX CSN Anchored Mobility Management

Proxy-MIP: MIP Client resides in ASN-GW

Client-MIP: MIP Client resides in MSS

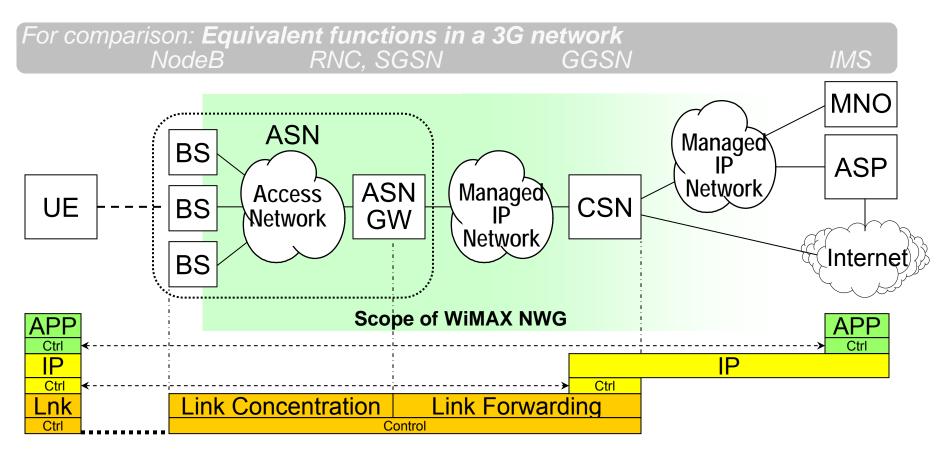© Nokia Siemens Networks   Mobile WiMAX4BWA2007/ Max Riegel / 2007-09-13

WiMAX Networking Considerations

- 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)

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Mobile WiMAX Data Path (User Plane)

End-to-end connectivity over Mobile WiMAX

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

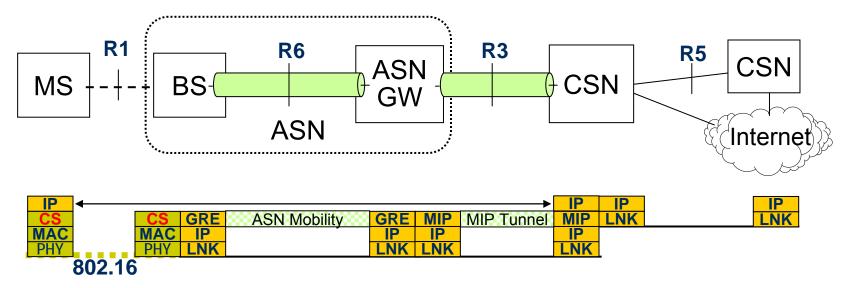| NodeB | RNC, SGSN | GGSN | IMS |

Scope of WiMAX NWG

All kind of wide-area access networks are following the same layering approach:
- 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

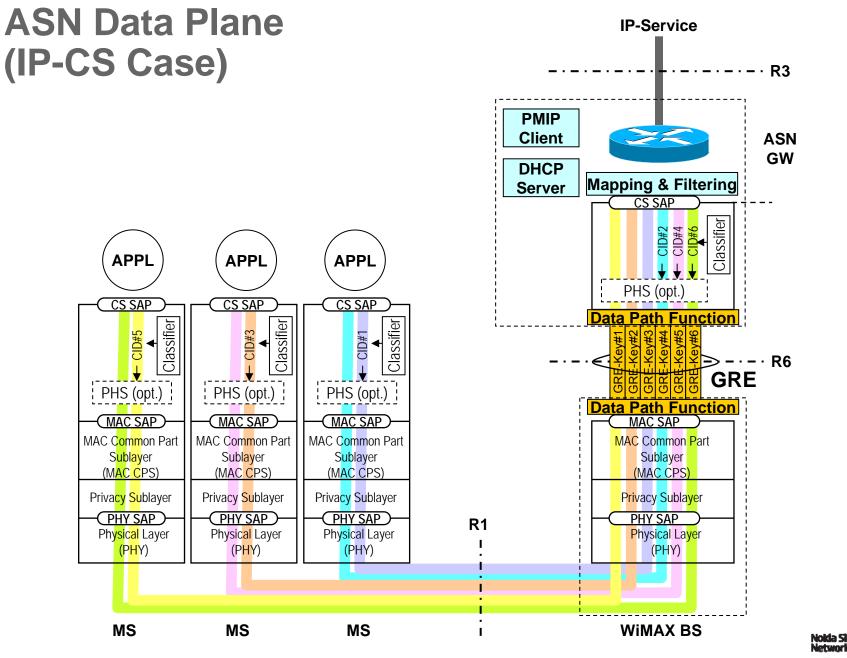**Nokia Siemens Networks**

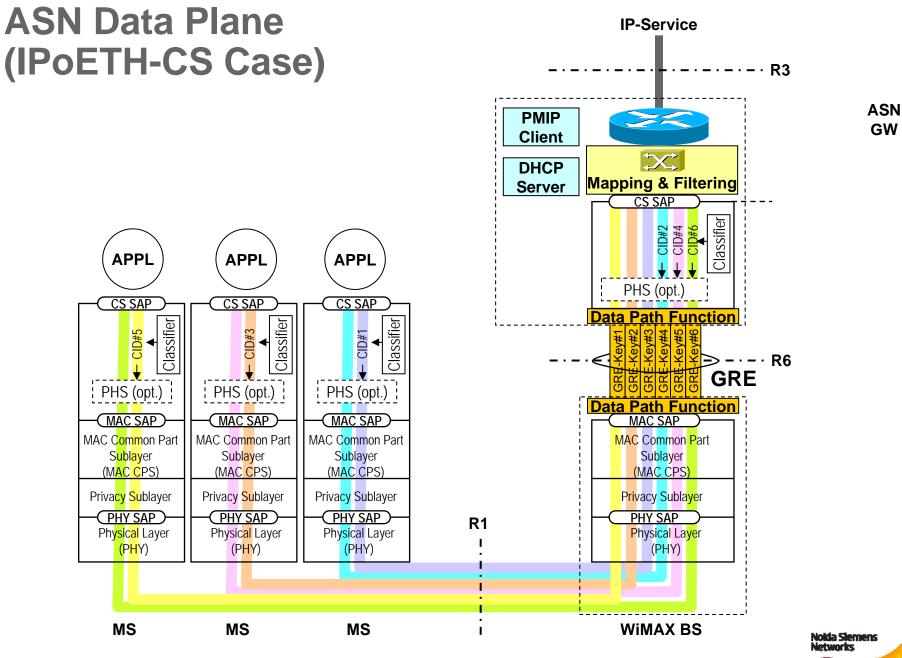# Tunneling packets through the WiMAX access network

The 802.16 Convergence Sublayer (CS) provides tunneling over the air.

- Tunnels are identified by the CID (Connection Identifier)
- Assignment of CIDs is performed in the BS/MS
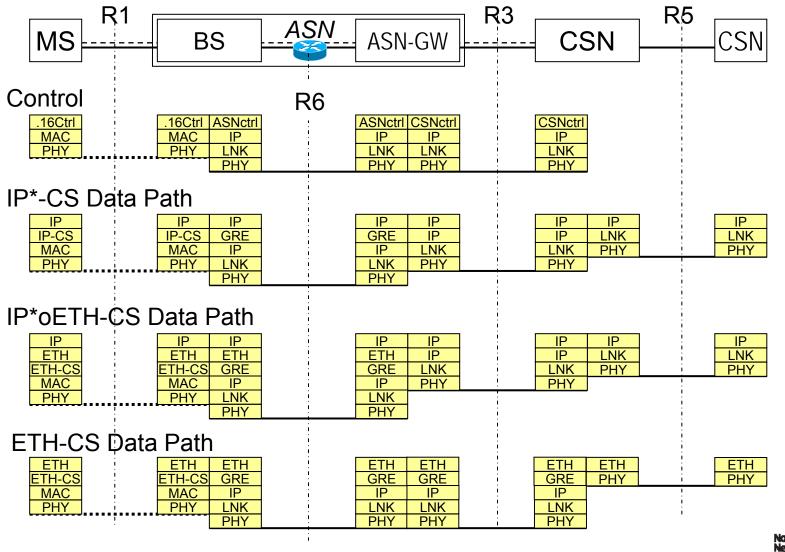- CIDs are used for differentiating QoS

ASN Data Plane (IP-CS Case)

ASN Data Plane (IPoETH-CS Case)

IP-Service

R3

ASN GW

PMIP Client

DHCP Server

Mapping & Filtering

CS SAP

CID#2 CID#4 CID#6 Classifier

PHS (opt.)

Data Path Function

GRE-Key#1 GRE-Key#2 GRE-Key#3 GRE-Key#4 GRE-Key#5 GRE-Key#6

R6

GRE

Data Path Function

MAC SAP

MAC Common Part Sublayer (MAC CPS)

Privacy Sublayer

PHY SAP

Physical Layer (PHY)

WiMAX BS

APPL APPL APPL

CS SAP

CID#5 Classifier

PHS (opt.)

MAC SAP

MAC Common Part Sublayer (MAC CPS)

Privacy Sublayer

PHY SAP

Physical Layer (PHY)

CS SAP

CID#3 Classifier

PHS (opt.)

MAC SAP

MAC Common Part Sublayer (MAC CPS)

Privacy Sublayer

PHY SAP

Physical Layer (PHY)

CS SAP

CID#1 Classifier

PHS (opt.)

MAC SAP

MAC Common Part Sublayer (MAC CPS)

Privacy Sublayer

PHY SAP

Physical Layer (PHY)

MS   **MS**   **MS**

R1

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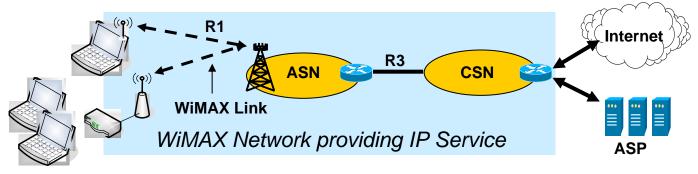# Control Plane and Data Path Protocol Layering

Wireless Ethernet

- Can be implemented like the wired case
  - Radio system provides p2p transport for Ethernet frames
- Wireless particularities
  - Shared transmission resource
    - Multiple transmissions for multicast messages
    - Native multicast support does not really help
  - Limited terminal power; terminal has to wake up to receive packets, even when packet is meaningless
    - Power issue is more critical than scarce transmission resource
- IETF 16ng working group is addressing the transport of IP over wireless Ethernet and provides a specification solving the particularities.
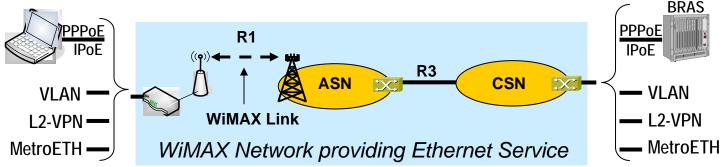
     Mobile WiMAX4BWA2007/ Max Riegel / 2007-09-13

Ethernet Services over Mobile WiMAX

IP Network Service vs. Ethernet Network Service

IP Network Service

R1

Internet

WiMAX Link

ASN — R3 — CSN

ASP

WiMAX Network providing IP Service

- The WiMAX network provides IP connectivity to the Internet and operator services for single hosts or multiple hosts behind a gateway.
  - Like a 3GPP or 3GPP2 mobile network

Ethernet Network Service

BRAS

PPPoE
IPoE

R1

WiMAX Link

ASN — R3 — CSN

VLAN
L2-VPN
MetroETH

PPPoE
IPoE

VLAN
L2-VPN
MetroETH

WiMAX Network providing Ethernet Service

- The WiMAX network provides plain Ethernet connectivity end-2-end.
  - Like a DSL network, but without wires.
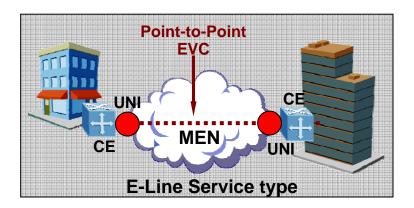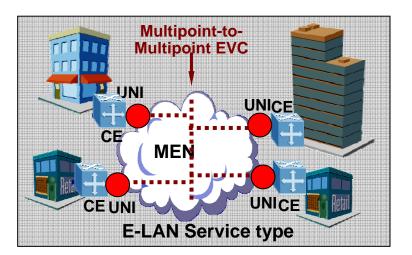
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ETH end-to-end Service Types according to Metro Ethernet Forum

E-Line Service used for

- Ethernet Private Lines
- Virtual Private Lines
- Ethernet Internet Access
- Point-to-Point upper layer services transport (IP-VPNs etc…)

E-LAN Service used for

- Multipoint L2 VPNs
- Transparent LAN Service
- Multicast networks
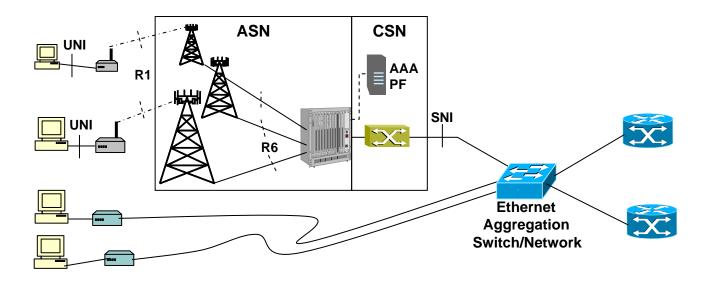

E-Line Service type

E-LAN Service type

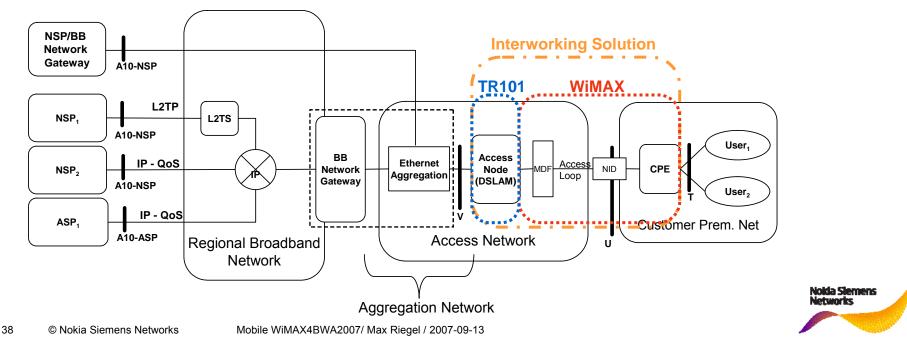# Deployment of Ethernet & VLAN in Mobile WiMAX

- Ethernet services may be mainly based on stationary deployment model of NRM

- Instead of AR, the CSN deploys a bridge for forwarding the user traffic (L2 instead of L3)

- AAA & PF support needed for dynamic establishment, configuration and accounting of Ethernet services inside the Mobile WiMAX network.
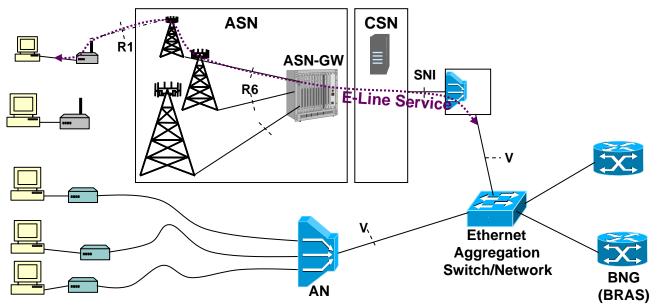
WiMAX Interworking with DSL: Interconnection over V-Interface

- V interface that supports Ethernet as the transport protocol
- Replace wired access loop by wireless access loop
- The wireless access network provides the same V-interface towards DSL Ethernet Aggregation as a DSLAM
  – Adopt a TR-101 Access Node to the WiMAX ASN
- Seamless integration of WiMAX into a DSL network
  – The WiMAX network provides only the L2 transport

Deployment of E-Line Service
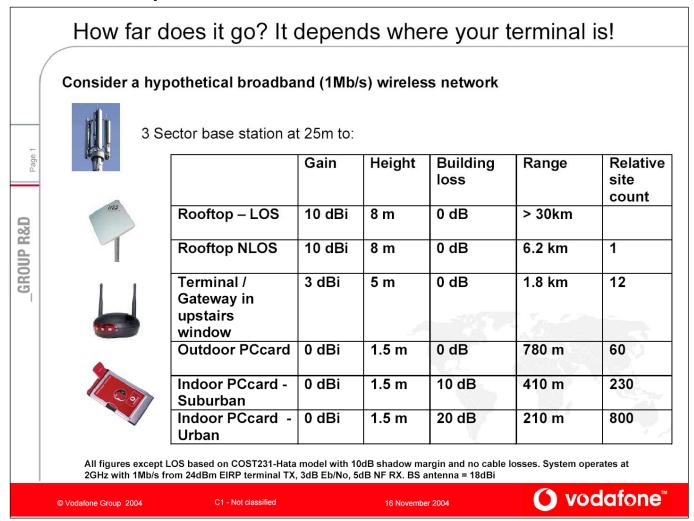# for WiMAX Interworking with DSL

- DSL Forum TR-101 deploys 802.1ad (QinQ) on V-Interface:
  - Full range of Customer-VLAN IDs preserved
  - Unique S-VID/C-VID pair (C-VID may be assigned by user)
  - S-VIDs to group of users assigned;
    - Service differentiation based on S-VIDs
- AAA & PF support needed for dynamic establishment, configuration and accounting of E-Line Service inside the Mobile WiMAX network.
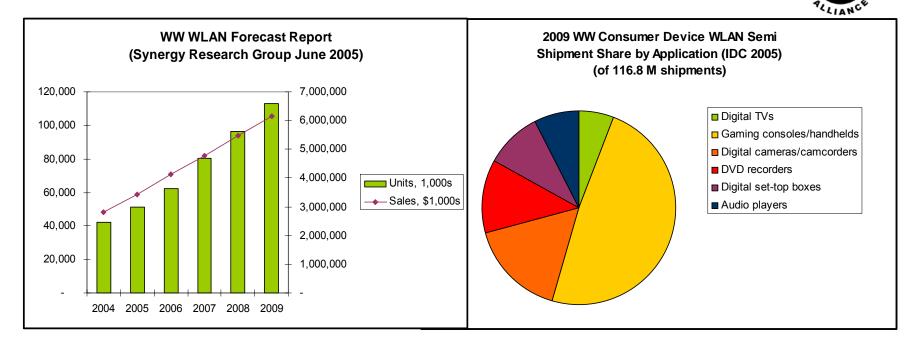 - Manual/static configuration is currently 'state of the art' in fixed networks

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Relays in Mobile WiMAX

Relays in Mobile WiMAX Motivation#1:

- Poor 'indoor' penetration, even more when in move

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

vodafone™

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Relays in Mobile WiMAX?
Motivation #2:

- There are a hundred million Wi-Fi devices:

WW WLAN Forecast Report
(Synergy Research Group June 2005)

- Units, 1,000s
- Sales, $1,000s

2009 WW Consumer Device WLAN Semi
Shipment Share by Application (IDC 2005)
(of 116.8 M shipments)

- Digital TVs
- Gaming consoles/handhelds
- Digital cameras/camcorders
- DVD recorders
- Digital set-top boxes
- Audio players

- And even more in future…
  - E.g. 55 -100 million Wi-Fi smart phones in 2010
    (SenzaFilli, IDC and ABI)

Source: Wi-Fi Alliance, 2005

IEEE802.16j: Mobile Multihop Radio Relays Improving Link Quality and Extending Coverage

- Radio relay stations helps improve SNR and extend coverage but more radio resource allocation may be needed
  - Tradeoff of cell capacity with range (coverage extension)
- With better SNR, higher coding schemes can be used instead of more robust ones with higher consumption of radio resources
  - Relay replaces low SNR link with substantially higher SNR multi-hop links
  - Additional overhead and delay
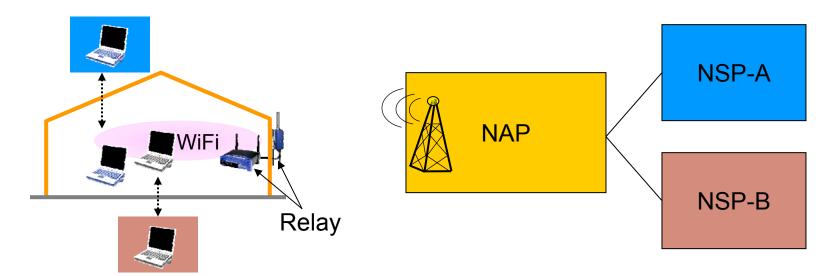
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Limitations of Radio Relays

- Deployment of 802.16j MMR impairs the interference level in the Mobile WiMAX spectrum
  - Relays are working in the same spectrum as the base stations
    - Relays are adding to the interference in neighbor cells
  - Uncontrolled/uncoordinated deployment of MMR dangerous to the network performance

- Not able to serve WiFi-only terminals out of a Mobile WiMAX radio link

- Nevertheless:
802.16j MMR is an excellent tool for operators to maintain the throughput and extend the coverage of their Mobile WiMAX networks
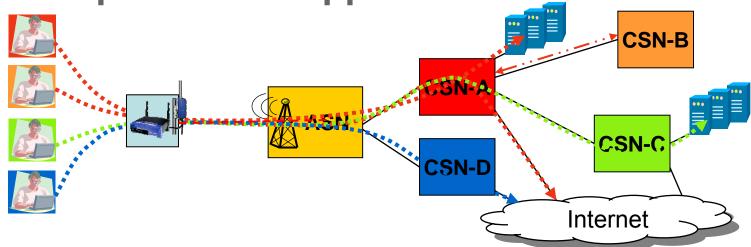
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WiMAX – Wi-Fi Relaying

- WiMAX – Wi-Fi relays can be applied to solve the indoor penetration issues of WiMAX
  - No radio issues because Wi-Fi uses different spectrum
- Nearly all WiMAX devices will be dual mode Wi-Fi/WiMAX devices
  - No issues to hand over the network connection from WiMAX to Wi-Fi
  - The WiMAX subscriptions should be usable behind a WiMAX - Wi-Fi relay
  - WiMAX subscriptions may belong to different NSPs
- Relays may be concurrently used by several Wi-Fi devices

Network Sharing and Roaming with Relay based on Multiple Hosts Support
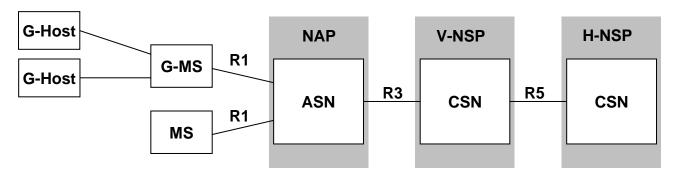

- Gateway-MS has special relation to Network Access Provider
  - Establishes control connection to AAA proxy in ASN
- User A gets access to the services of CSN-A over the G-MS
  - Authentication is provided by AAA server in CSN-A
- User B gets Internet Access over G-MS and CSN-A
  - Roaming without data forwarding to home
- User C gets access to his services over CSN-A
  - Roaming with data forwarding to home
- User D gets Internet Access over G-MS and CSN-D
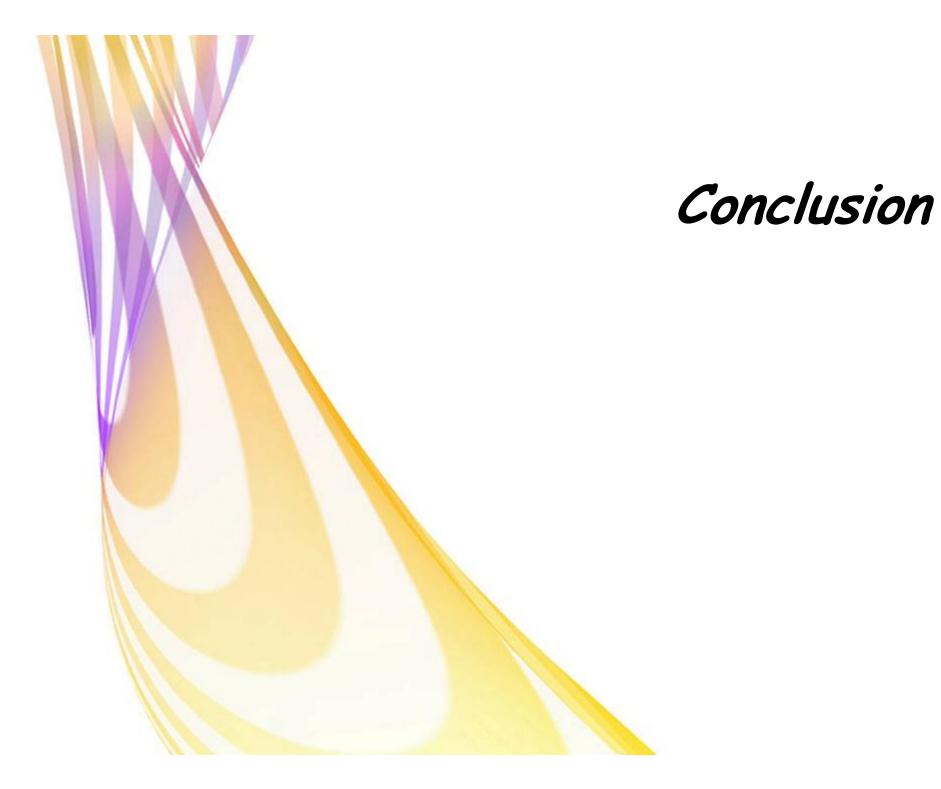
G-MS in the path is not visible to any of the CSNs

Coming soon:
Mobile WiMAX with Multiple Hosts Support

- Feature of the coming Release 1.5 of WiMAX Network Spec.

- Provides special support for
  - Gateway-MS (G-MS)
    - Mobile WiMAX SS/MS that provides the multiple hosts support
  - Gateway-Host (G-Host)
    - Host attached to the G-MS to leverage the WiMAX network facilities.
    - Host with direct or indirect subscription to access the WiMAX network

- G-Host appears to the network like an ordinary Mobile WiMAX MS with full QoS support.
  - NATs not feasible in nomadic and mobile deployments

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Conclusion

Conclusions

- The successful introduction of mobile broadband wireless access requires a different kind of mobile access network.

- Mobile WiMAX has defined a new mobile access network architecture fully aligned to the Internet business model.

- Mobile WiMAX introduces a clean separation of the access network from the core functions to enable network sharing and scalability from small to extremely large deployments.

- The WiMAX Network Reference Model facilitates interoperability for all the essential business interfaces.

- The Mobile WiMAX network supports Ethernet based services like DSL or Metro Ethernet in addition to plain IP connectivity.

- Broadband wireless access networks require relays for providing indoor coverage.

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The End

Questions, Comments?

Thank you for your attention!