Mobile WiMax
Overview and Architecture

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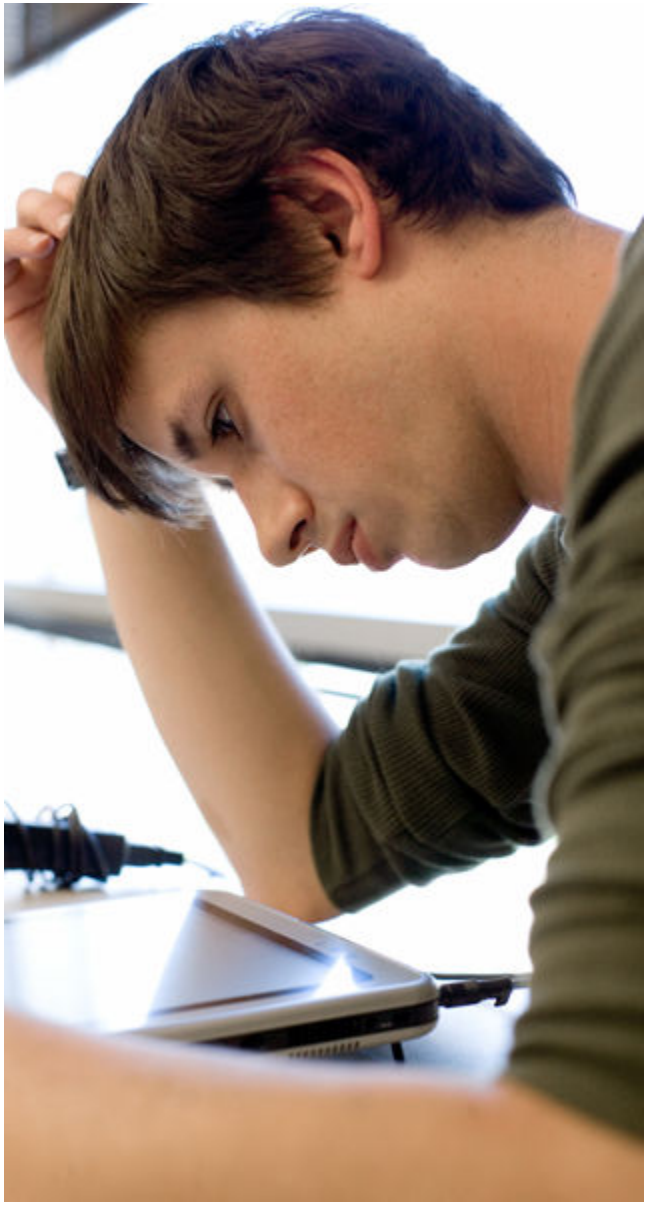
WiMAX

Worldwide Interoperability For Microwave Access

Agenda

- WiMAX Introduction
- WiMAX Forum Update
- Radio Interface
- Core Architecture
- Cisco WiMax Products
- Q & A



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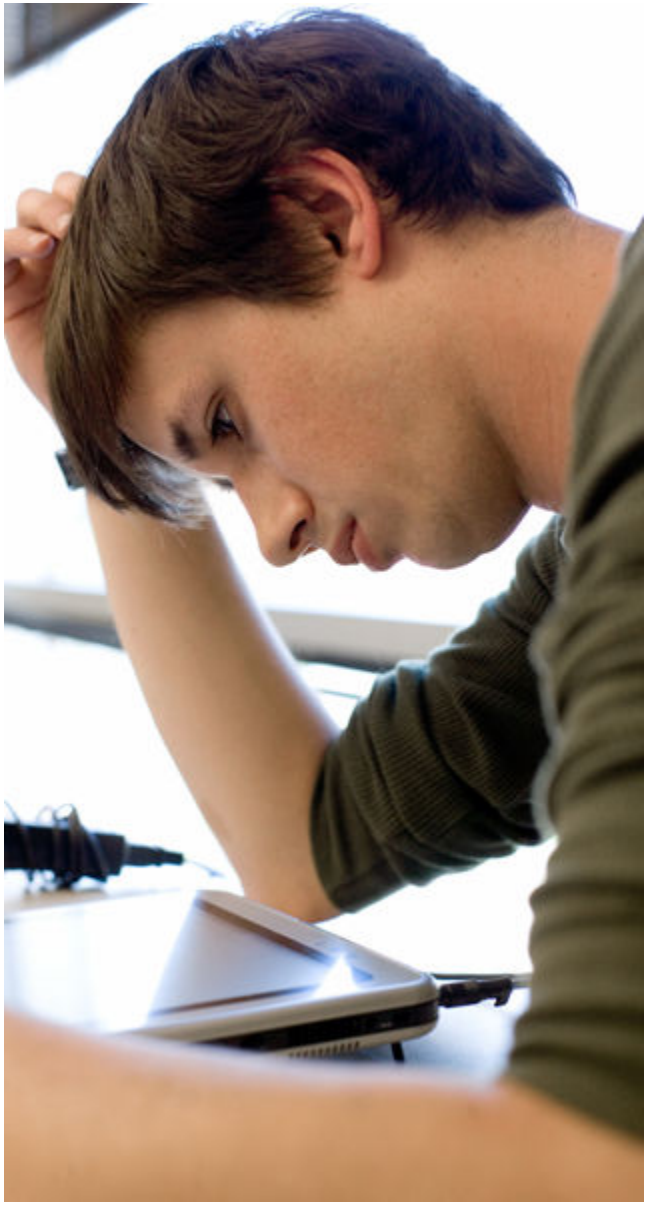


IMT-2000 Approval of WiMAX

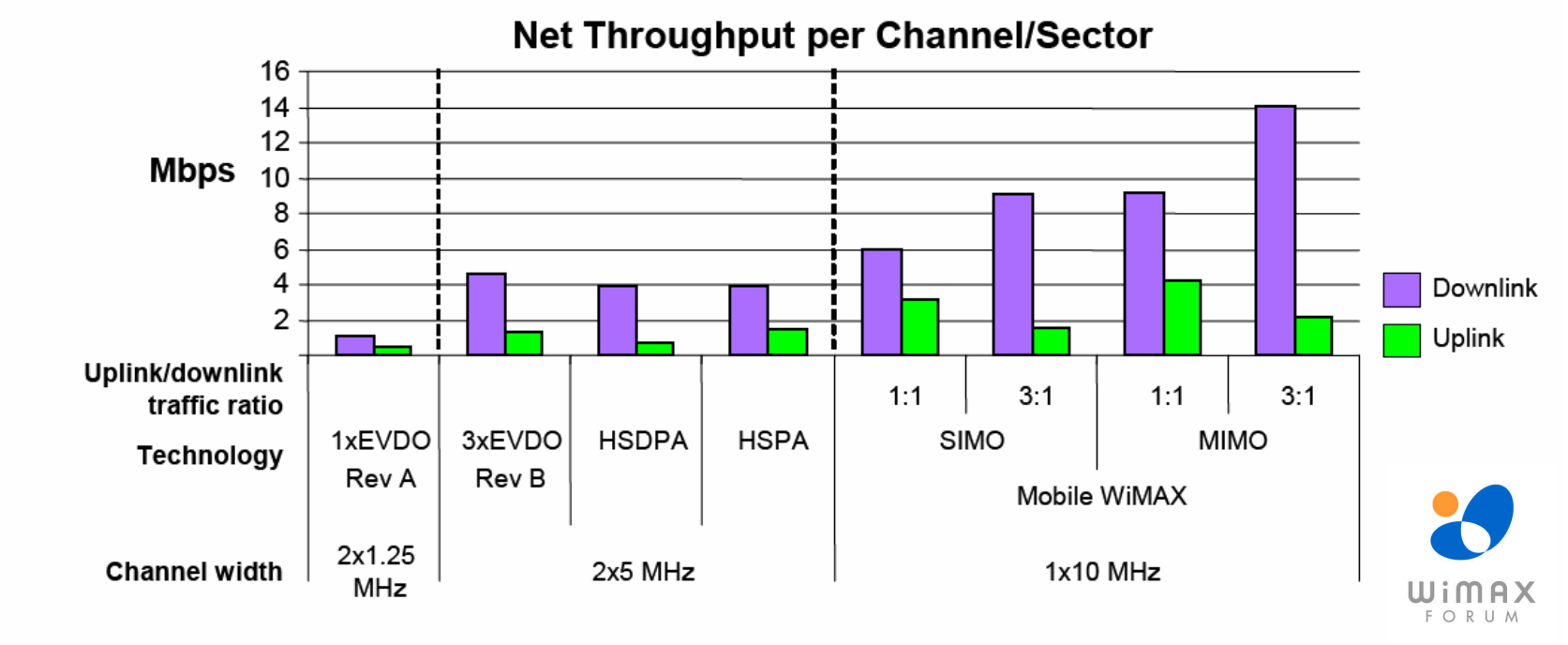
- The ITU-R approved the WiMAX Forum's version of IEEE Standard 802.16 as an IMT-2000 technology’
- This significantly escalates opportunities to deliver mobile internet in the the 2.5-2.69 GHz band, for both rural and urban markets.
- This is the first time that a new air interface has been added to the IMT-2000 set of standards since the original technologies were selected nearly a decade ago.
- WiMAX technology currently has the potential to reach 2.7 billion people.

WiMax Standards

- IEEE 802.16 – specifies radio aspects of WiMax
  - 802.16-2004 (known as 802.16d) – Fixed WiMax
  - 802.16e-2005 – Mobile WiMax
  - 802.16m – next generation of WiMax
- WiMax Forum – specifies subsets of 802.16 functionality for certification and the network architecture
  - WiMax System Profile Release 1
  - WiMax Forum Network Architecture Release 1

Broadband Wireless Market Adoption

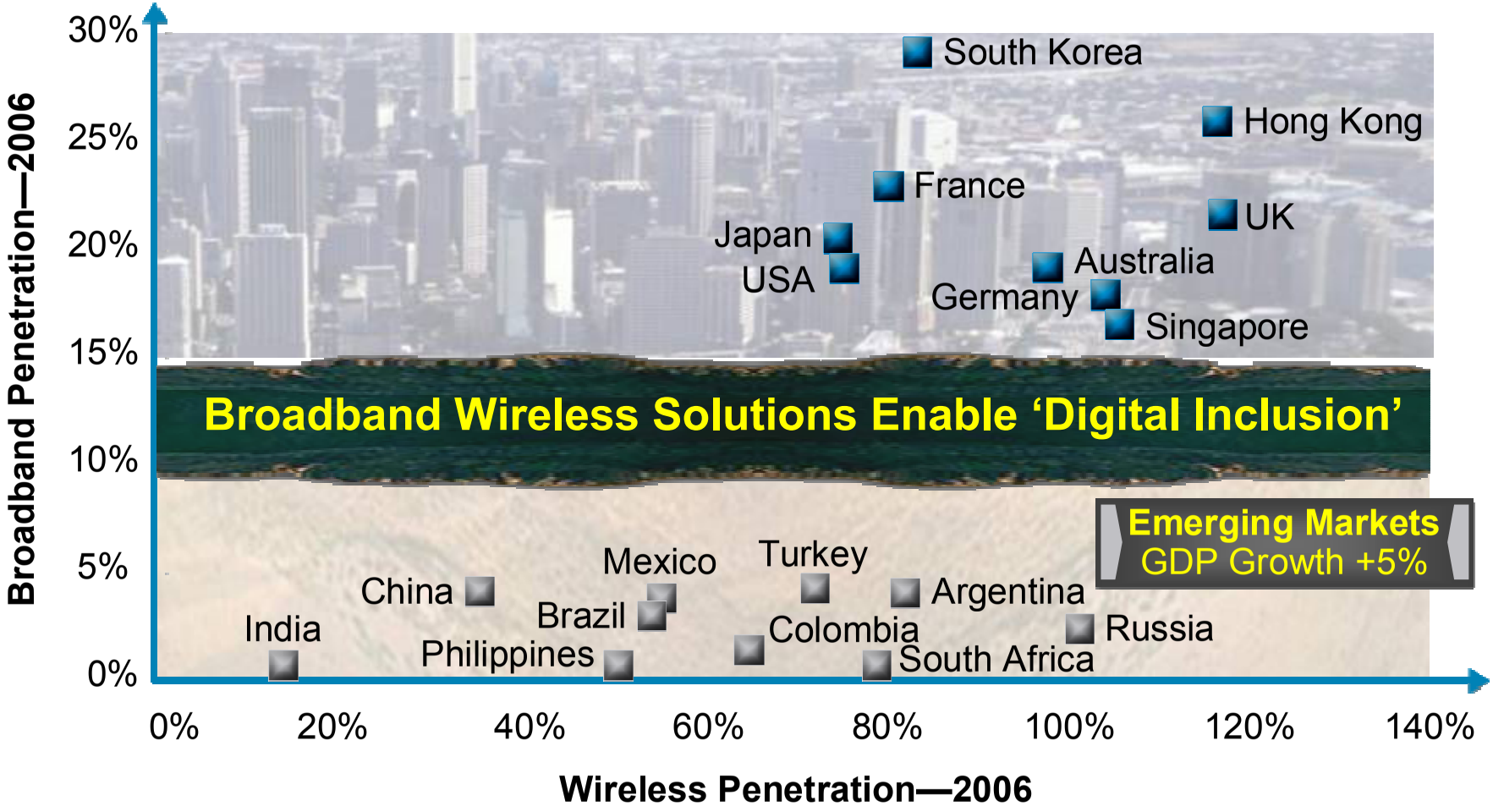
Reason for WiMAX as preferred technology is simple…



- **Higher throughput per subscriber, lower latency, built for IP**
- **Business Case for 802.16 better than traditional 3G systems**
- **Models the successful "plug & play" scheme of Wi-Fi**
- **First licensed-RF technology to enable "personal wireless broadband"**
- **Taiwan picked WiMAX due to extraordinary expense of 3G**

The Real Opportunity

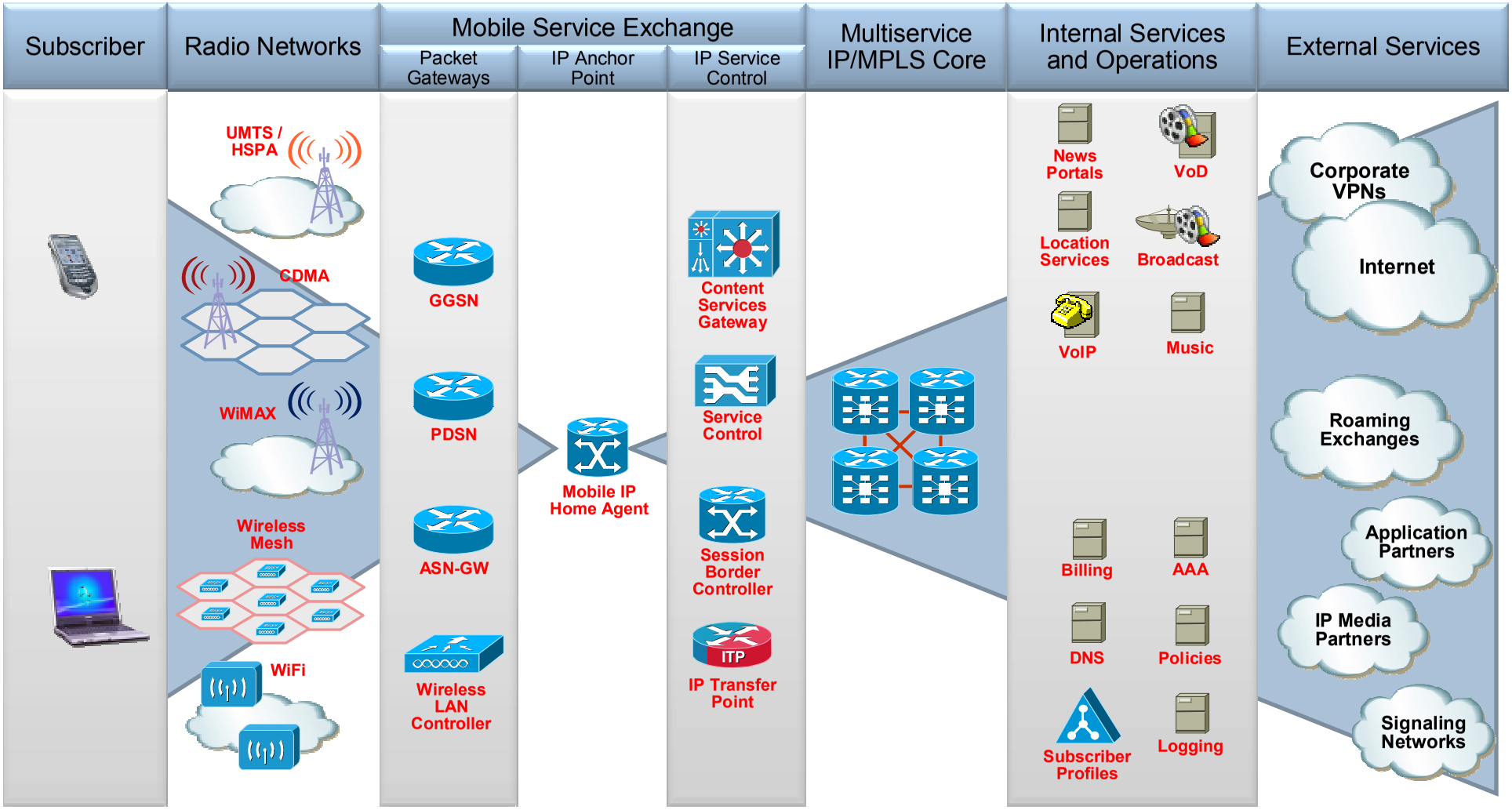
Country Transformation and 'Digital Inclusion'



Source: EIU, Telegeography, Point Topic, Cisco Analysis

Cisco IP Next Generation Networks

IP Forms the Foundation for True Mobility for WiMAX



WiMAX Services

Residential Services

- Internet Access
- Parental Control
- Residential Voice
- Walled Garden

Business Services

- Managed Services
- L2 VPN
- L3 VPN (MPLS)
- Internet access and presence
- Backhaul of Hotspots

Wholesale Services

- Internet Access
- Voice Services

Consumer Services

- Internet Access
- Voice Services

WiMAX Value Summary

- WiMAX value proposition is for operators to make money out of delivering services on the **new Internet model**
- WiMAX is free from the legacy wire line-cellular because it's roots are derived **from the Internet**
- WiMAX will match speeds of LTE (current proposal of 20 MHz now part of 1.5 Release.)
- WiMAX will have a cellular-based flavor of multicasting available via HSPA called Multimedia Broadcast Multicast Service or MBMS
- WiMAX embraces **QoS** controls and tools which allow operators to embrace multi-tier service pricing and level marketing.
- WiMAX is excellent where countries – locations have no existing infrastructure

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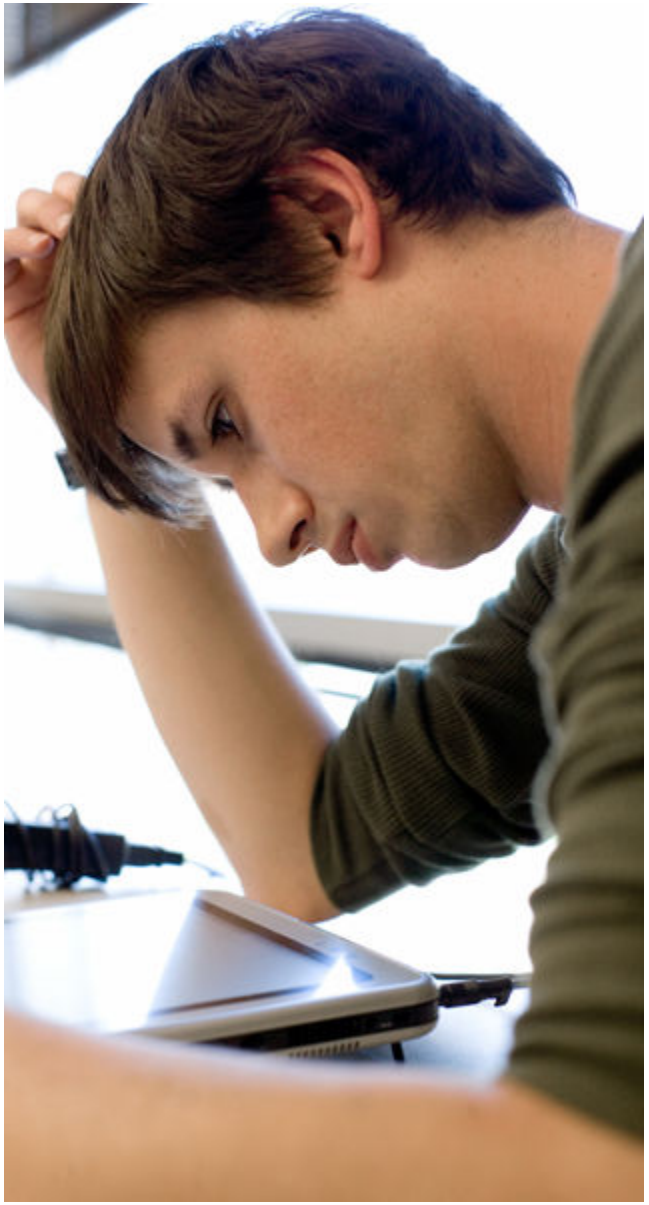


The WiMAX Forum – 519 Members

27%

137 Content Eco-systems

17%

87 Components Silicon Mfrs

31%

161 Service Providers

25%

127 System Vendors

•Deliver a trusted certification process

•Develop a framework for a high performance end to end IP mobile network architecture supporting all usage models

•Promote WiMAX as the leading business model to deliver global wireless broadband services

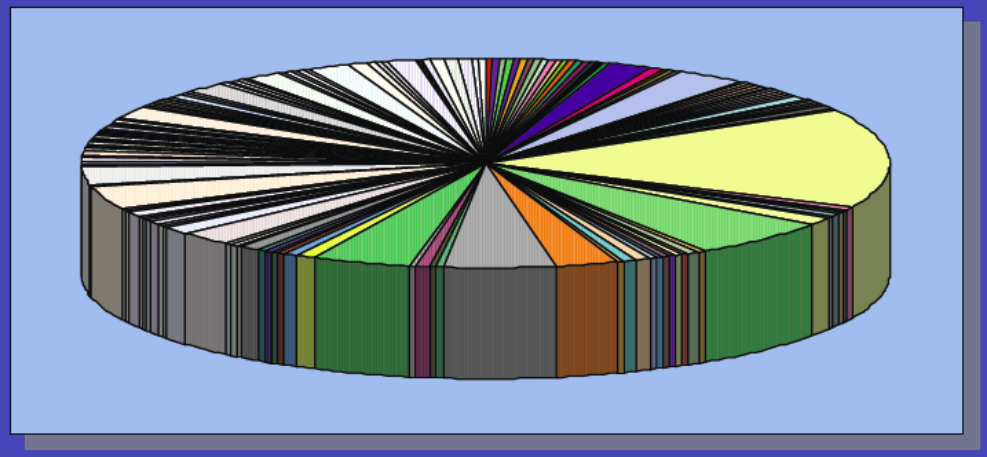
•WiMAX Forum contributes to foster a thriving ecosystem

WiMAX forum's nine working groups

- **Applications Working Group:** Define applications over WiMAX™ that are necessary to meet core competitive offerings and that are uniquely enhanced by WiMAX technology.
- **Certification Working Group:** Handles the operational aspects of the WiMAX Forum Certified program.
- **Evolutionary Technical Working Group:** Maintains existing OFDM profiles, develops additional fixed OFDM profiles, and develops technical specifications for the evolution of the WiMAX Forum's OFDM based networks from fixed to nomadic to portable, to mobile.
- **Global Roaming Working Group:** Assures the availability of global roaming service for WiMAX networks in a timely manner as demanded by the marketplace.
- **Marketing Working Group:** Influences WiMAX technology adoption worldwide. Promotes WiMAX products, brands and standards, which form the basis for global interoperability of wireless broadband Internet anytime anywhere.
- **Network Working Group:** Creates higher level networking specifications for fixed, nomadic, portable and mobile WiMAX systems, beyond what is defined in the scope of 802.16.
- **Regulatory Working Group:** Influences worldwide regulatory agencies to promote WiMAX-friendly, globally harmonized spectrum allocations. *Chair: Tim Hewitt, BT*
- **Service Provider Working Group:** Gives service providers a platform for influencing BWA product and spectrum requirements to ensure that their individual market needs are fulfilled.
- **Technical Working Group:** The main goal is to develop technical product specifications and certification test suites for the air interface based on the OFDMA PHY, complementary to the IEEE 802.16 standards, primarily to allow interoperability and certification of Mobile Stations, Subscriber Stations and Base Stations conforming to the IEEE 802.16 standards.

WiMAX Intellectual Property Rights

- Dispersed distribution of ownership of US patents*
- No single company has a dominant IPR position.



1550 patents are distributed among 330 companies

Of the 23 Companies that hold more than 10 Patents…
74% are WiMAX Forum members, representing 82% of the patents held in concentrations of 11 or more patents per company

** Based on independent survey of relevant and potentially relevant patents/applications for United States*

Source: Schwegman, Lundberg, Woessner & Kluth
Oct 2006

Mobile Certification in 2008

Release 1.0 Wave 1

Mandatory testing:
Key functionality, including QoS, AES, PKMv2, handoff, H-ARQ, power control, sleep and idle mode and header compression

Release 1.0 Wave 2

Mandatory testing: Additional test on handover, QoS, power saving and IPV6

Base Station

Optional Modules:
MIMO
Beamforming
Ethernet I/O
MBS

Mobile Station

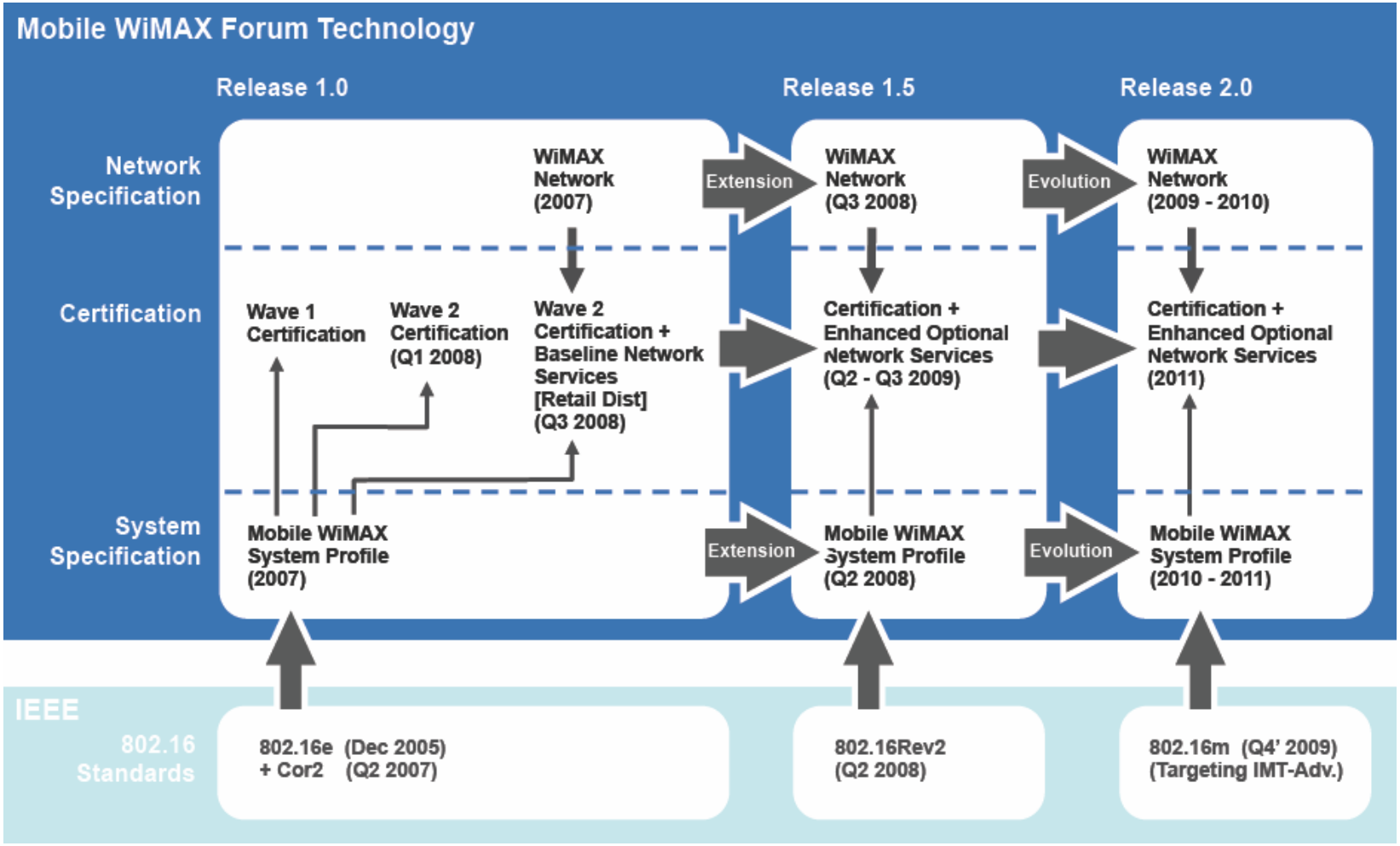
Mandatory Testing:
MIMO
Beamforming
MBS

Optional:
Ethernet I/O

Backward Compatible More Features Tested

Mobile Wimax Roadmap

Mobile WiMAX Technology Evolution Vision



A fully backward compatible evolution on standards and products

Projections subject to change

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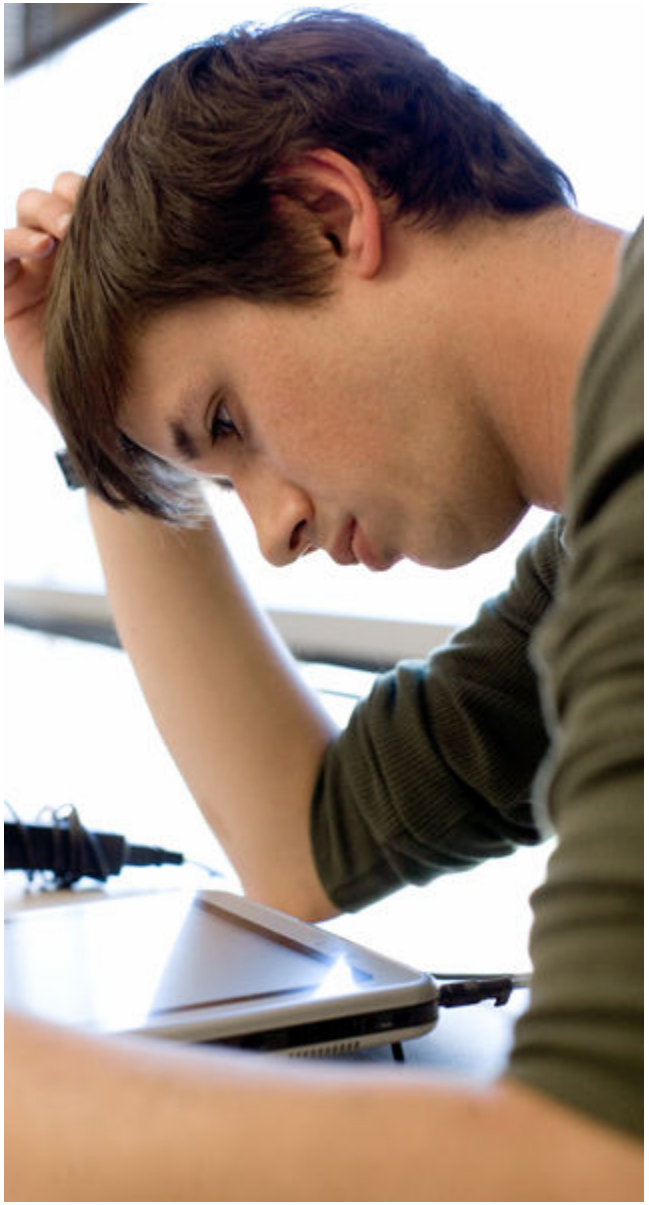
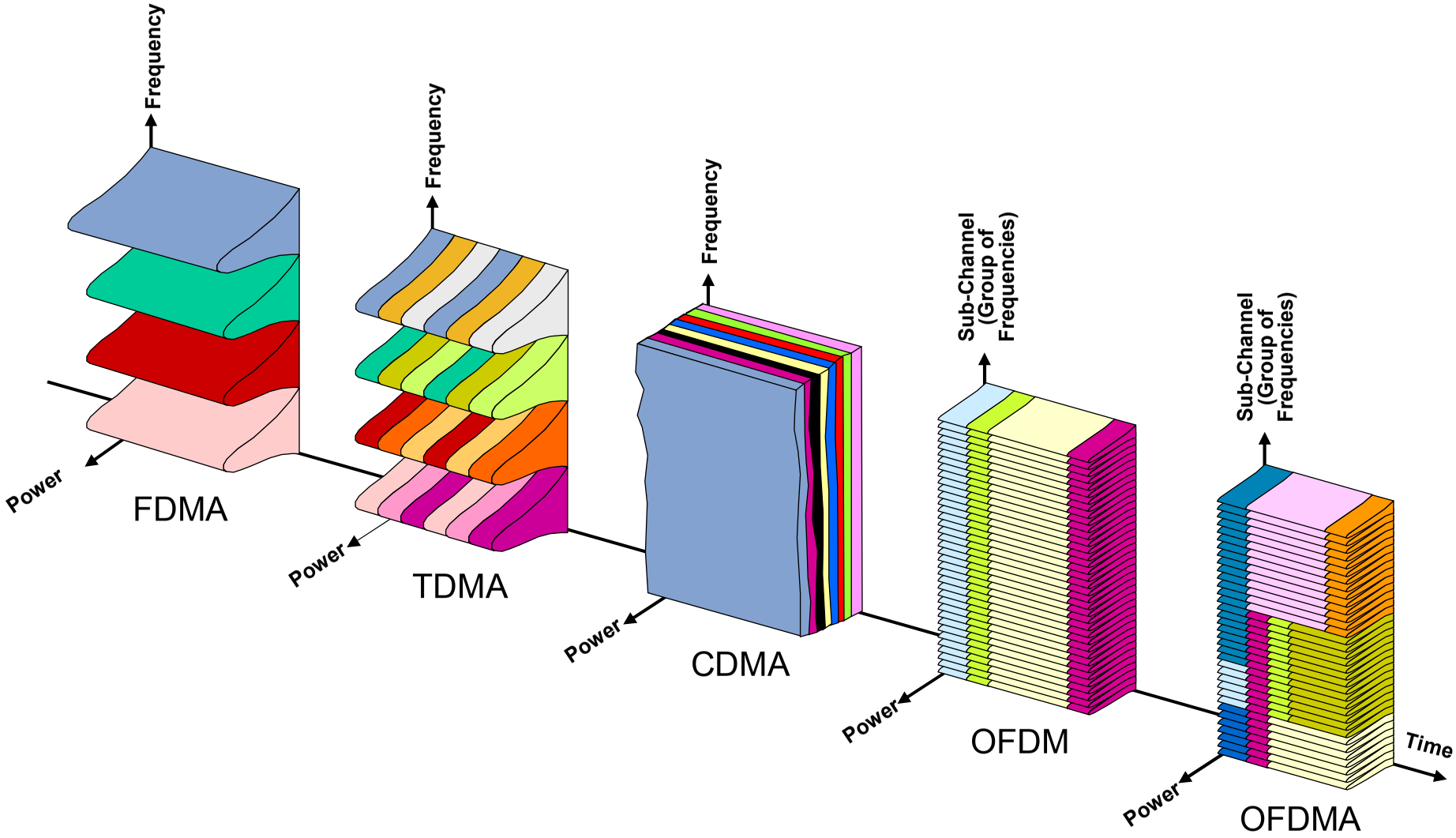


Multiple Access Technologies



802.16 vs. 802.16-2004 and 802.16e-2005 Features

	802.16	802.16-2004	802.16e-2005
Date completed	December 2001	June 2004	December 2005
Spectrum	10-66 GHz	< 11 GHz	< 6 GHz
Channel Conditions	LOS only	NLOS	NLOS
Bit Rate	32-134 Mbps in 28 MHz channel bandwidth	Up to 75 Mbps in 20 MHz channel bandwidth	Up to 15 Mbps in 5 MHz channel bandwidth
Air Interface	TDMA with TDD and FDD	OFDM & OFDMA with TDD & FDD	Scalable OFDMA with TDD & FDD
Mobility	Fixed	Fixed, portable	Nomadic portability, Full mobility
Channel Bandwidths	20, 25, 28 MHz	Scalable 1.5 to 20 MHz	Scalable 1.5 to 20 MHz
Typical Cell Radius	2-5 km	7-10 km	2-5 km

Source: WiMAX Forum as of December, 2007

Scalable-OFDMA

- Why go *scalable*?

  Various bandwidth sizes are required to meet numerous worldwide needs

- What does it mean to be scalable?

  # of sub-carriers available is dependent on the bandwidth size

- 802.16e-2005 standard specifies bandwidths ranging from 1.25 MHz to 20 MHz

- WiMAX Forum supports:

  3.5 MHz with 512 FFT

  5 MHz with 512 FFT

  7, 8.75, or 10 MHz with 1024 FFT

WiMAX – Time Dimension

- The **Sampling Rate** is a basic concept in WiMAX. For the bandwidths that are multiple of 1.25 MHz (that is, 1.25, 5, 10, and 20 MHz) it is defined as 28/25 of the bandwidth, but for other bandwidth a different fraction is used. In the case of 5 MHz, the Sampling Rate is 28/25×5 MHz = 5.6 MHz.
- The **Symbol Period PS** is a basic time unit defined as 4 × the inverse of the Sampling Rate: 4/5.6 MHz = 0.7143 µs. Base on the PS, the following time intervals are defined:

  OFDM Symbol (or just "**Symbol**", for short)= 144×PS = 102.86 µs

  Useful Time Tu of a symbol = 8/9 of the Symbol duration = (8/9)×102.86 µs = 91.43 µs

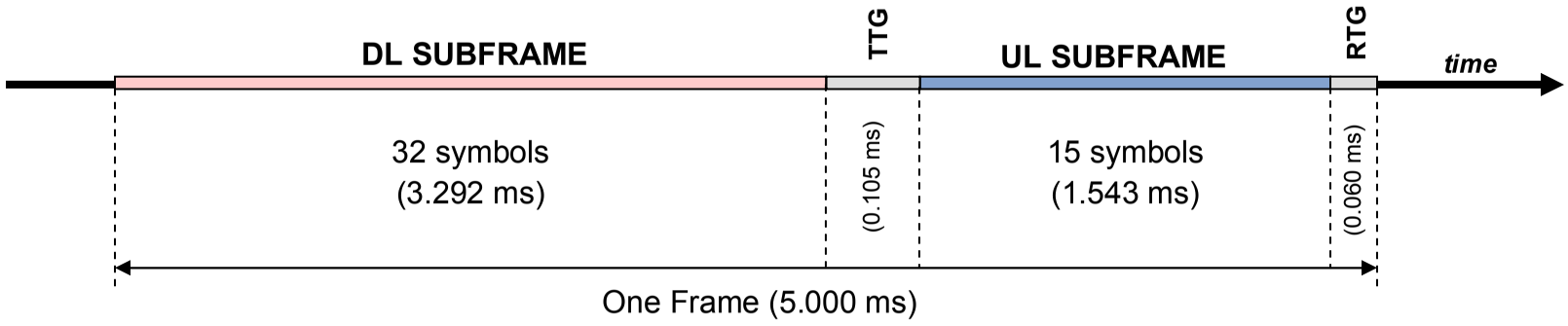
  Transmit-to-Receive Gap (TTG) = 148×PS = 0.105 ms

  Receive-to-Transmit GAP (RTG) = 84×PS = 0.060 ms

  Frame = 47×Symbol + 1×TTG + 1×RTG = 5.0 ms

Primary limit to 8.5Km Range

- The 47 symbols in a frame are subdivided into **DL Sub-frame** (with 35 to 26 symbols) and **UL Sub-frame** (with the reminding 12 to 21 symbols). The number of symbols in each sub-frame is configurable. Navini uses the combination of 32 symbols in the DL and 15 in the UL



WiMAX – Frequency Dimension

- **Tone** (a.k.a. “sub-carrier”): a sinusoidal voltage, which is modulated with coded information and then converted to RF. This RF is radiated by the transmitting antenna and carries the information to the receiving antenna at the speed of light

  There are 512 tones in 5 MHz of bandwidth

- **Tone Separation**: 1 / Useful Symbol Time = 1 / Tu = 1 / 91.43 = 10.94 kHz
- **Types of tones**:

  Active Tones

  Data tones – for data transmission

  Pilot tones – continuous signal for channel tracking and synchronization

  Null tones –not used for transmission

  Guard bands

  DC carriers

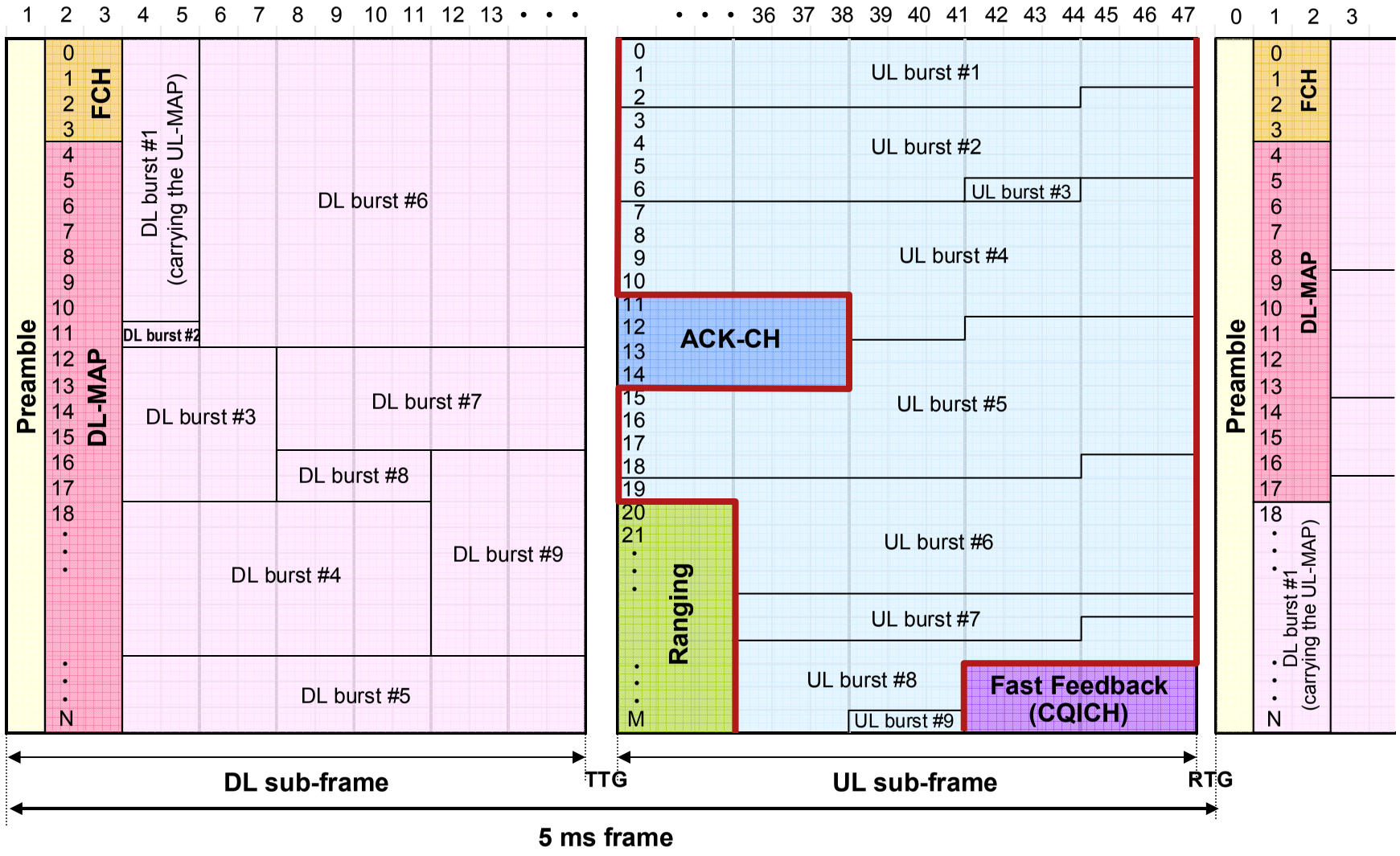
- **Sub-Channel**: a group of *active* tones
- **Permutation**: a scheme for grouping active tones into sub-channels

  Some of the tones in a sub-channel are pilot tones, others are data tones

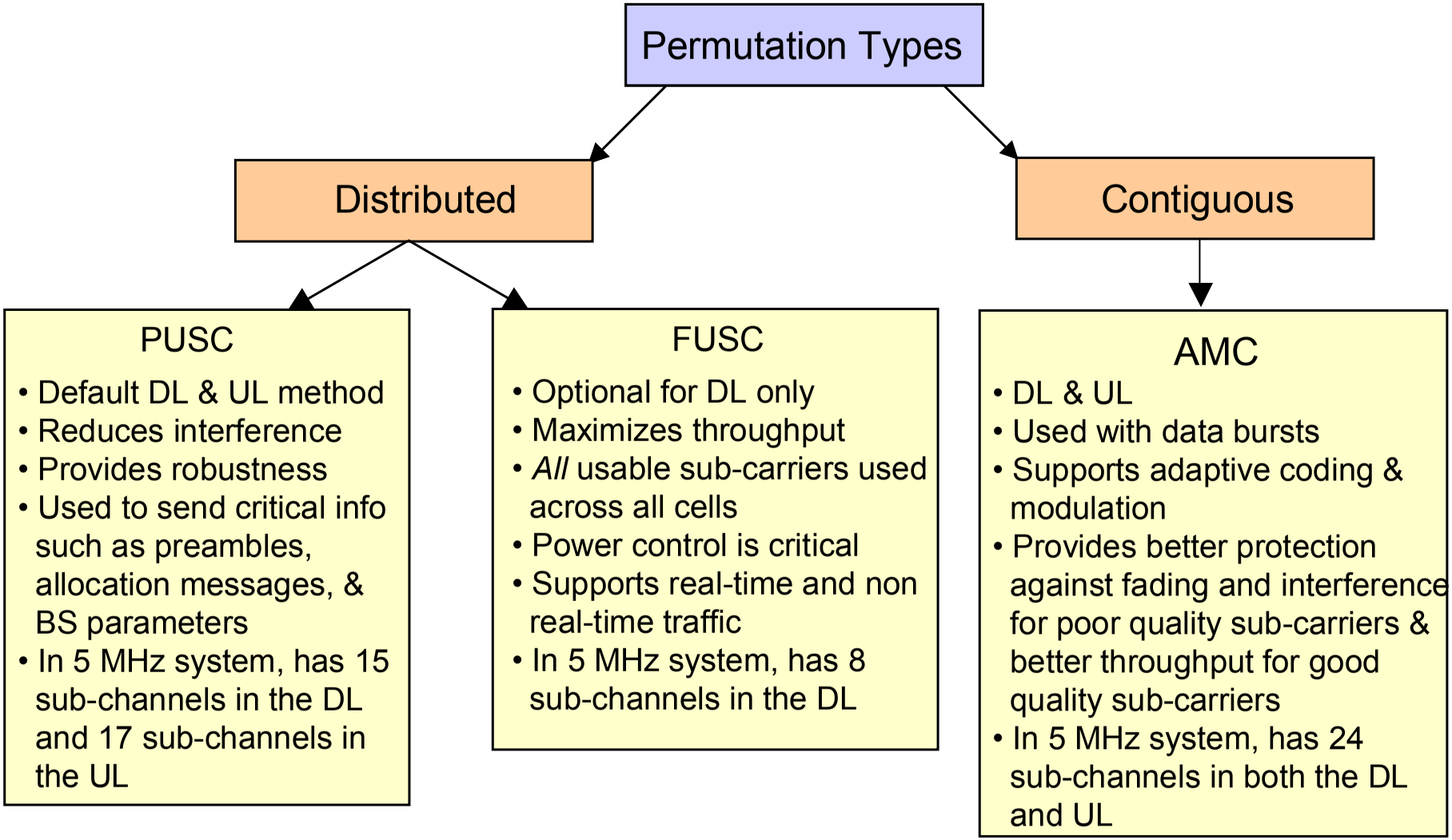
  Which tones are used for data and which for pilot may change from one symbol to the next and depends on the permutation scheme

  The tones making up a sub-channel may or may not be adjacent

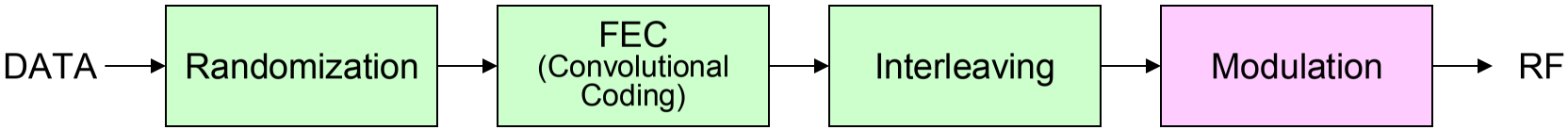
Mobile WiMAX TDD Frame Structure



PUSC, FUSC, and AMC



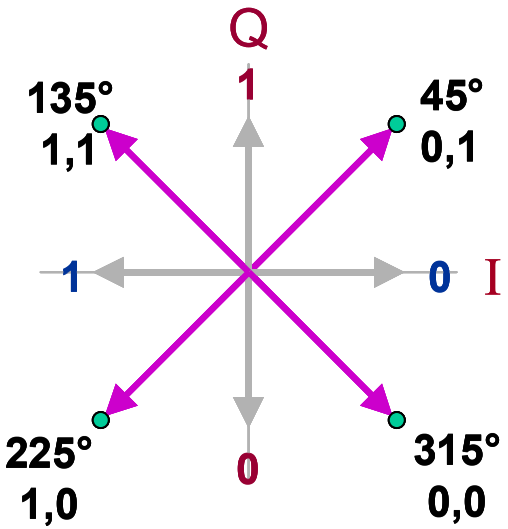
Channel Coding & Modulation



- **Randomization** – about 50% of the original bits change (1→0 and 0→1), the rest do not. The result is a stream with about the same number of 1's as of 0's
- **Forward Error Correction** – redundancy is added to make possible a certain degree of error detection and correction at the receiving end
  - Reed Solomon – not suported at this time
  - Convolutional Coding – characterized by the "constraint length" and the "rate"
- **Interleaving** – the coded bits are rearranged in a predefined way so that the bits that were produced together are not transmitted together
  - Helps fight noise bursts
- The randomized, coded and interleaved bits are mapped into the desired modulation scheme and the data tones are modulated and then radiated

QPSK and 16QAM

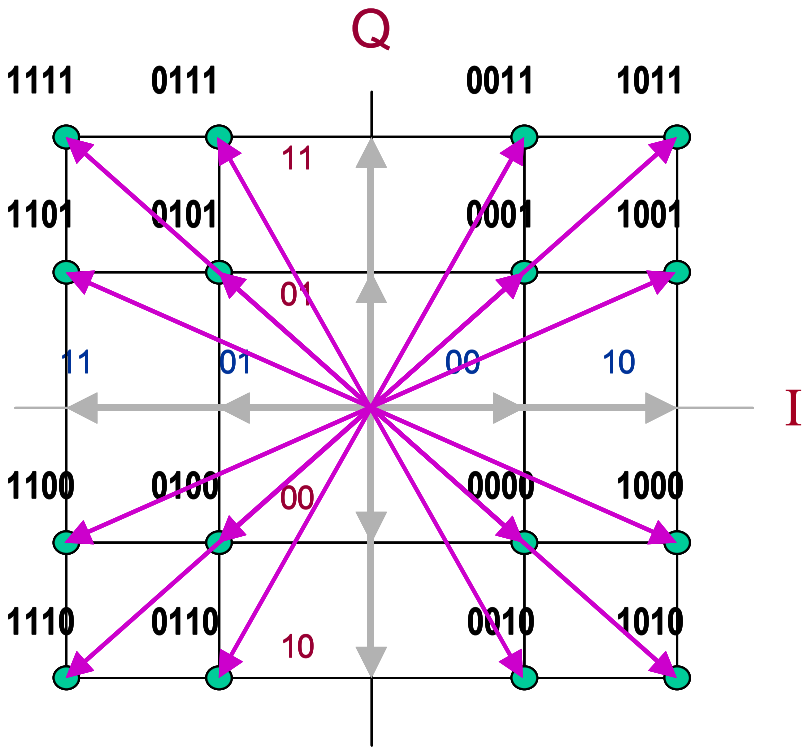
QPSK



4 possible states
(each state = 2 bits)

00, 01, 10, 11

16QAM

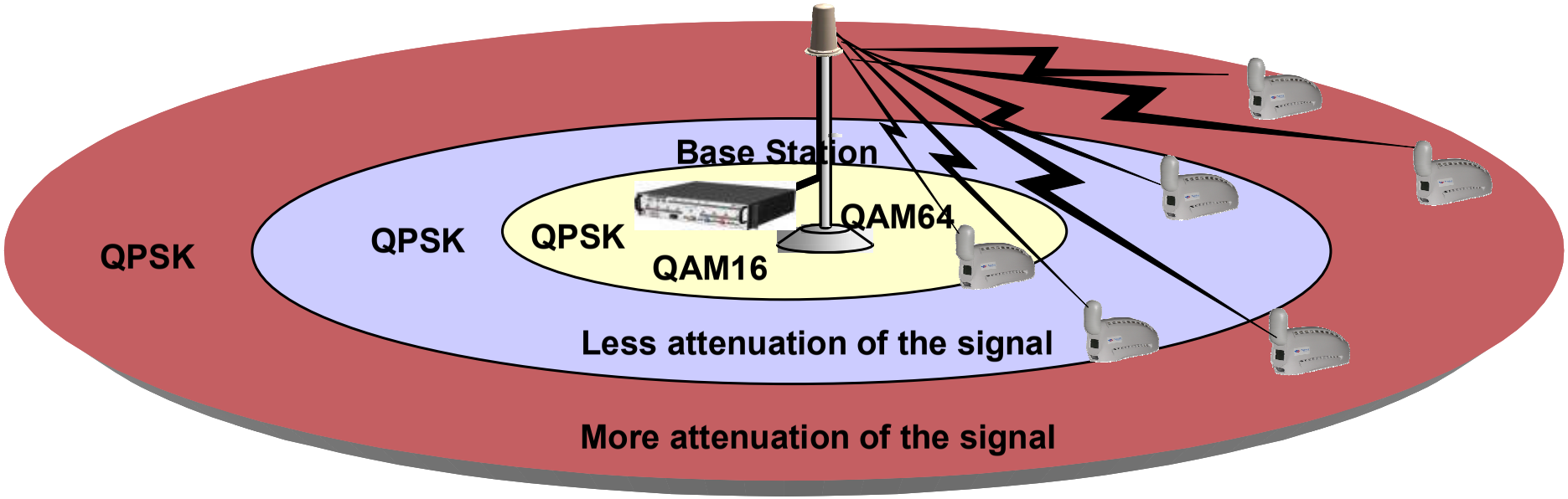


16 possible states (each state = 4 bits)

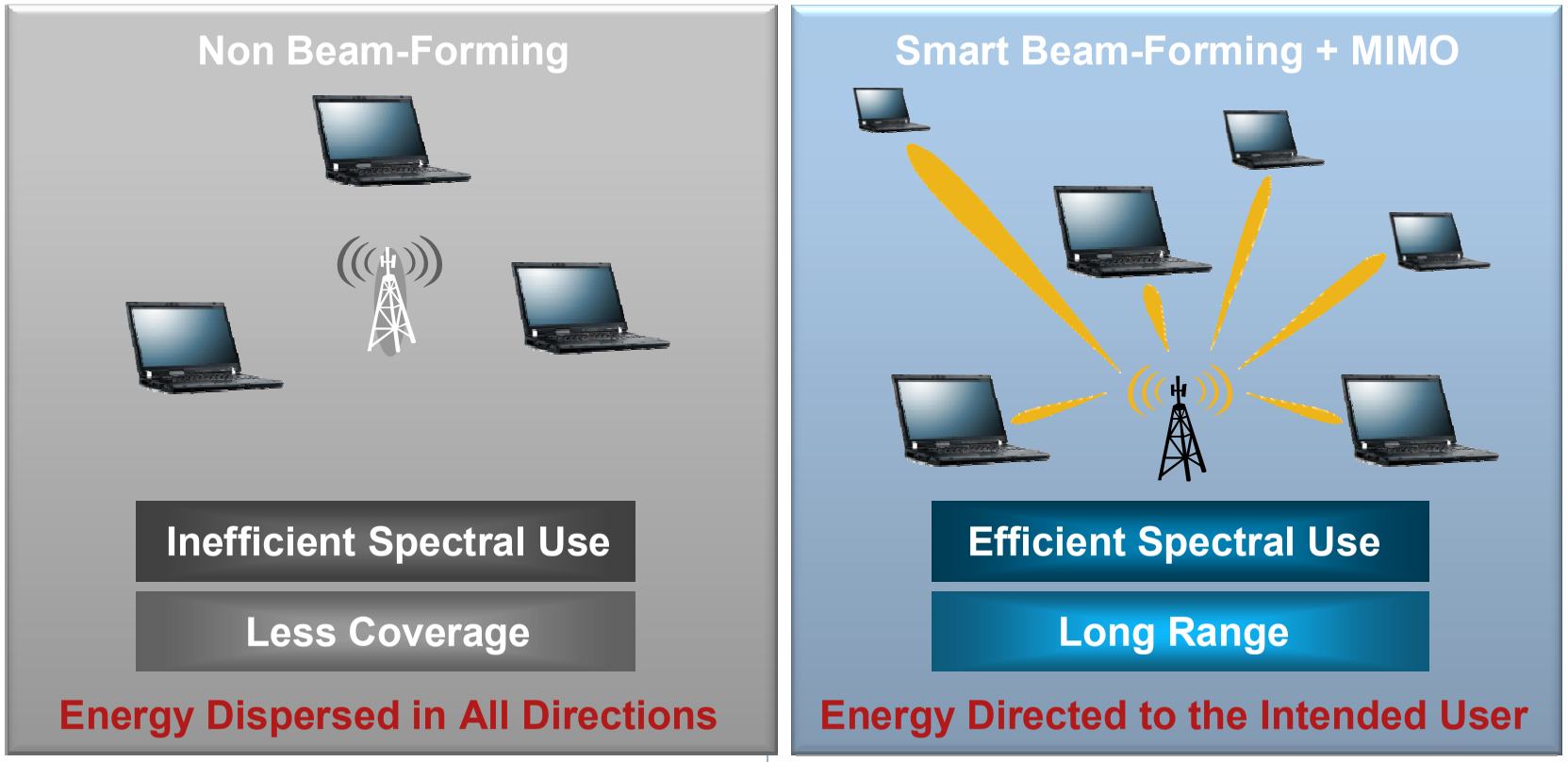
0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111,
1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111

Each state is defined either by the distance from the center (**amplitude**) and the angle (**phase**) OR by the horizontal (**I**) and vertical distance (**Q**) from the center

Adaptive Modulation



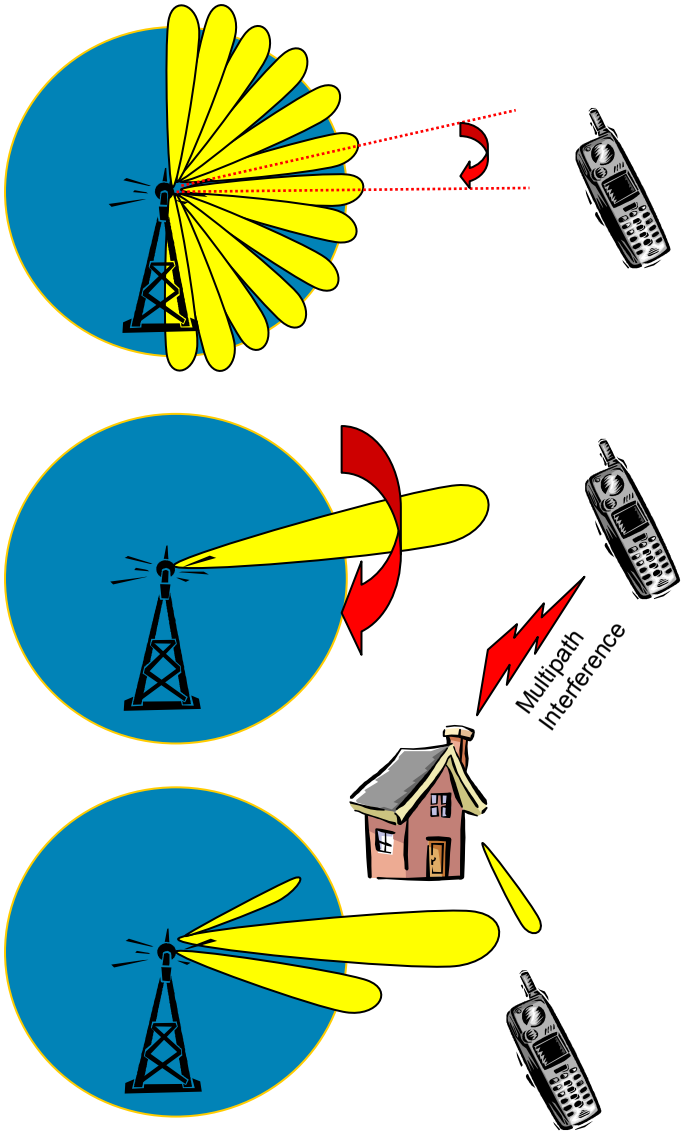
Beamforming Basics



- Makes Zero-install, plug-n-play, mobile, personal BB a reality
  - Downlink performance improved by 18dB {20log(N)}– more capacity & building penetration
  - Uplink performance improved by 9dB {10log(N)} – larger cell sizes
- Additional capacity and better frequency reuse due to reduced interference
- Uplink gain permits reduced radiated power by subscriber devices – size, cost & battery life

Cisco Beamforming

Not all Beamforming approaches are equal…



Switched Lobe Smart Antenna (Vendor X)

Cheap, but inflexible, Uses multiple small, immobile “sub sectors”. Base Station selects which sub sector to use based on strongest signal received. Suffers from limited gain.

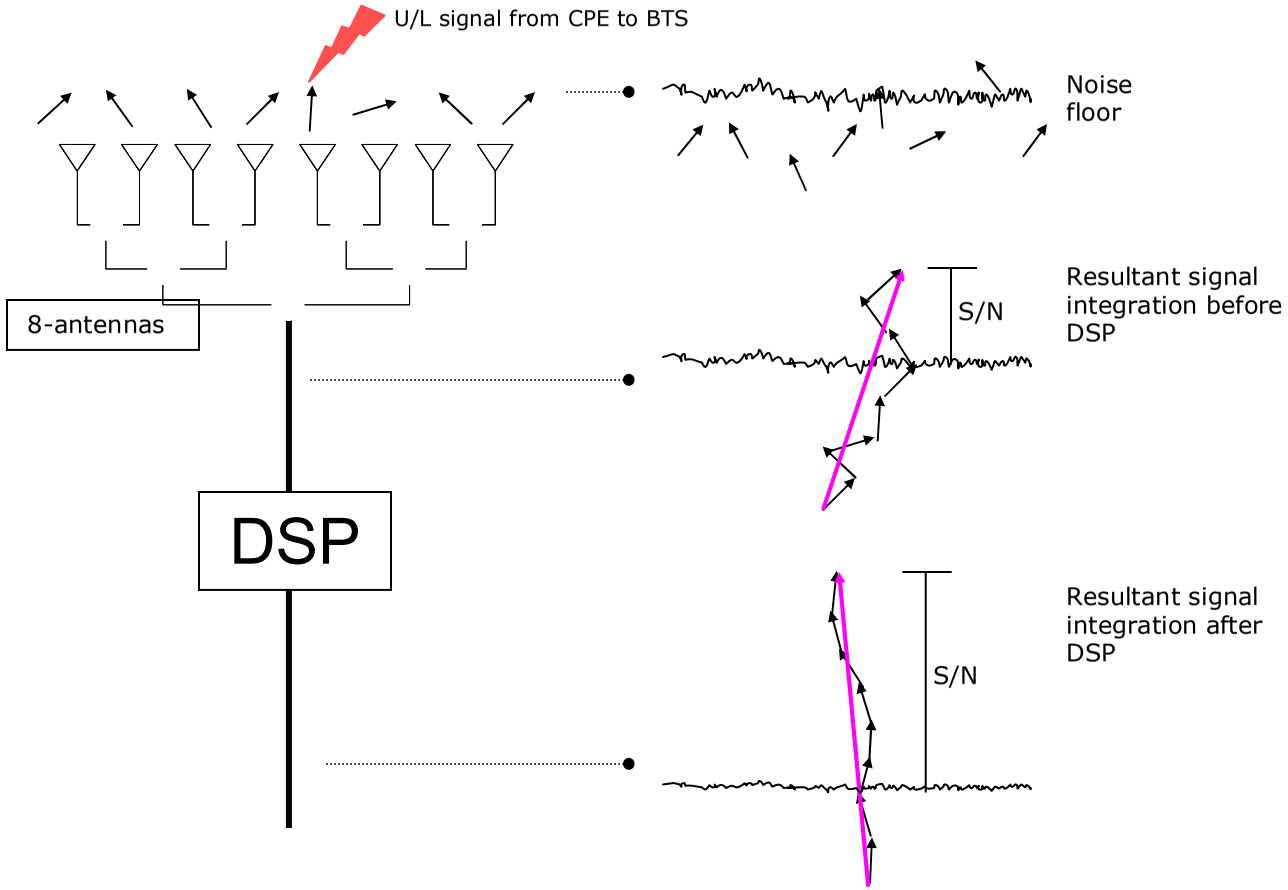
Dynamically Phased Array/Beam Steering (Vendor Y)

Uses multiple small, immobile “sub sectors”. Base Station selects which sub sector to use based angle of arrival, and steers beam. Suffers from multipath interference.

Adaptive Antenna Array - Cisco

Best performance. System measures angle, phase and strength of arrival from uplink sounding. Uses results to send downlink using all available multipaths to add constructively at the source.

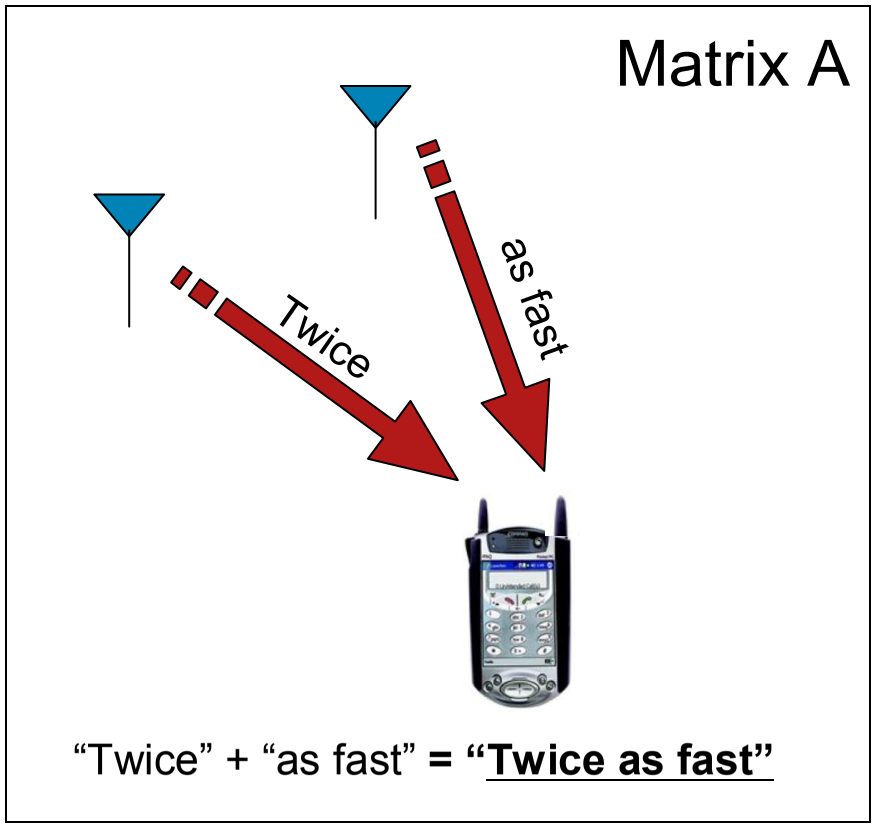
How Beamforming Works

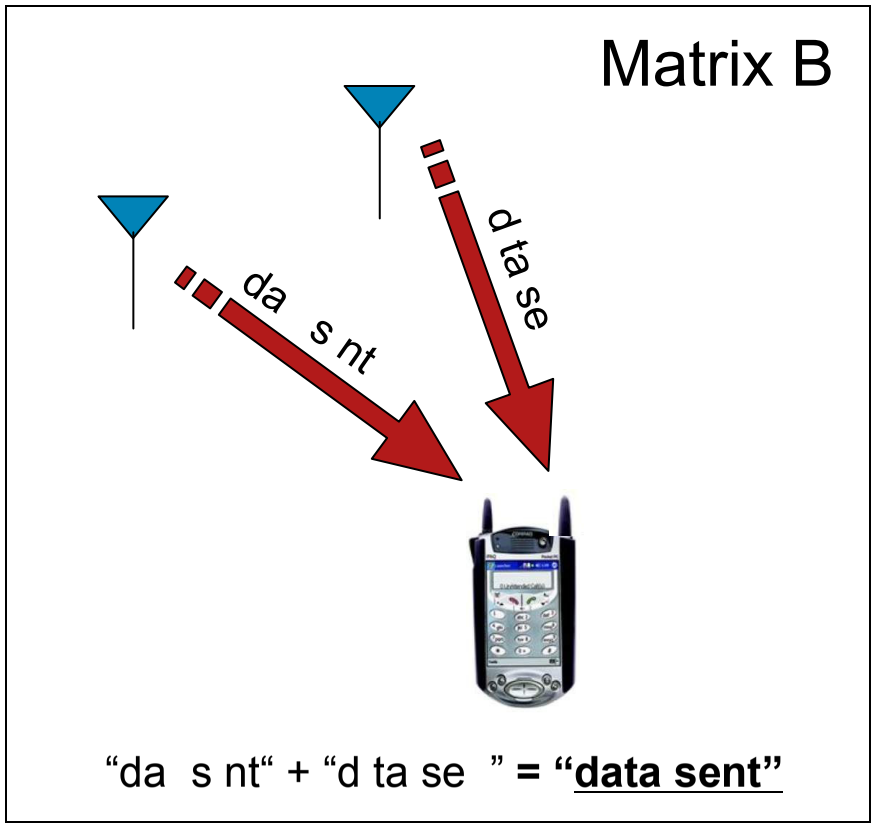


- **The DSP engine applies complex algorithms on the I & Q portions of the signals such that they would add more "constructively" with the resultant U/L output signal being 9 dBs larger than a non-BF system.**
- **Similarly on the D/L in combination of the DSP engine & 8 PAs, the 8-signals coming from 8 different antennas add constructively within a couple of meters from the CPE resulting in a signal that is 18 dB larger than the CPE would have seen had the BTS had only 1 antenna.**

Multiple Input/Multiple Output (MIMO)

- MIMO systems employ multiple antennas at both Base Station and SS device
- Two types of Simple MIMO





- In Wave 2, WiMAX certified SS devices must be able to support both types of MIMO

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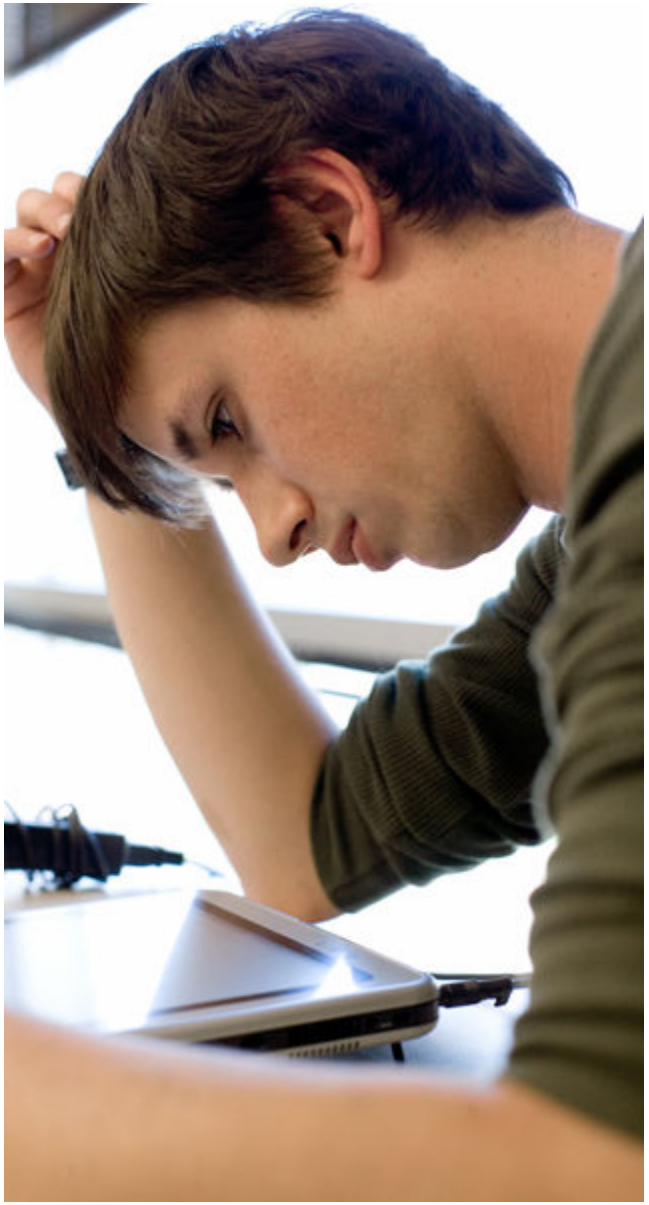
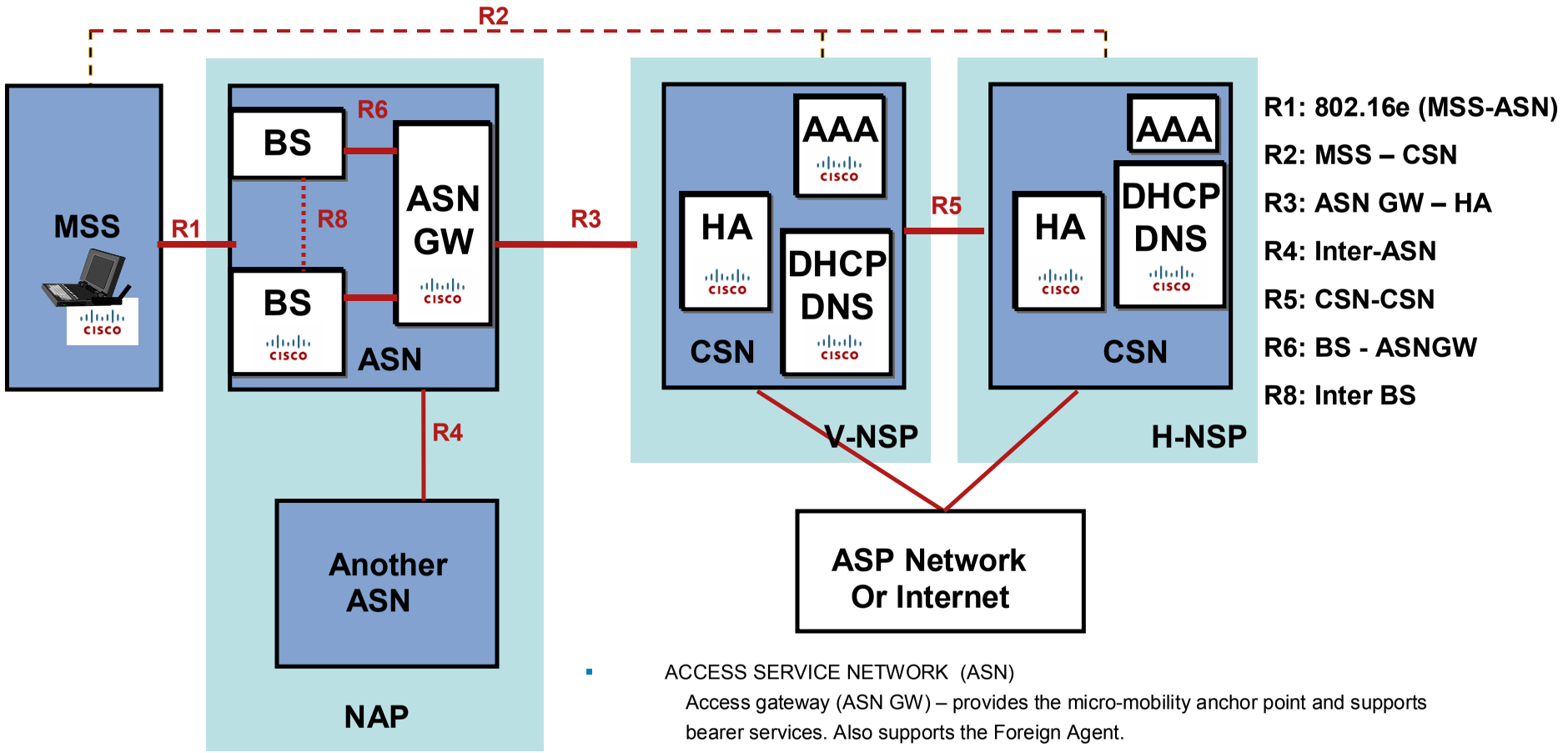


WiMAX End to End Network Reference Model



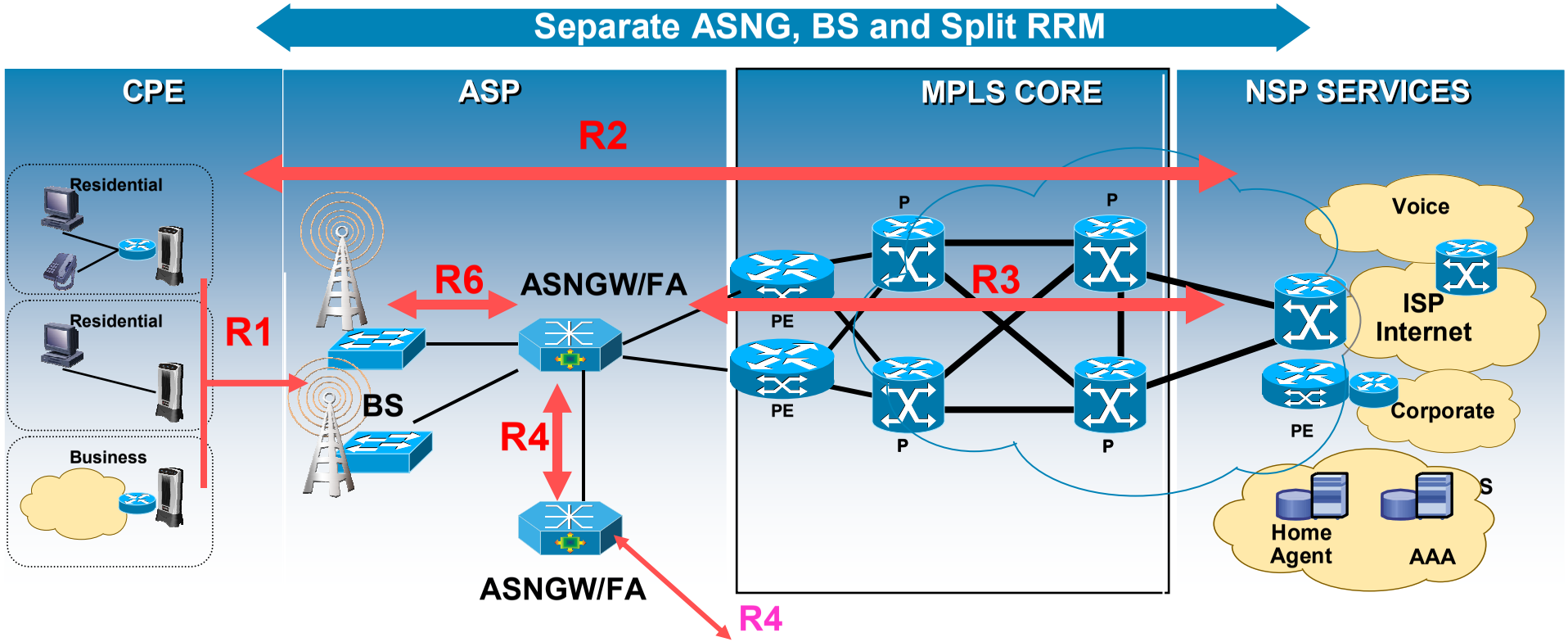
MSS – Mobile Subscriber Station

NAP – Network Access Provider

NSP – Network Service Provider

- ACCESS SERVICE NETWORK (ASN)
  - Access gateway (ASN GW) – provides the micro-mobility anchor point and supports bearer services. Also supports the Foreign Agent.
  - Base station (BS) – provides the radio dependent functions and has limited IP functionality
- CORE SERVICES NETWORK (CSN)
  - Home agent (HA) – provides the macro-mobility anchor point and supports bearer services , if roaming/mobility is desired.
  - Other Network Elements such as AAA, DHCP servers and more are also in the CSN.

ASN Profile A - removed from Standards



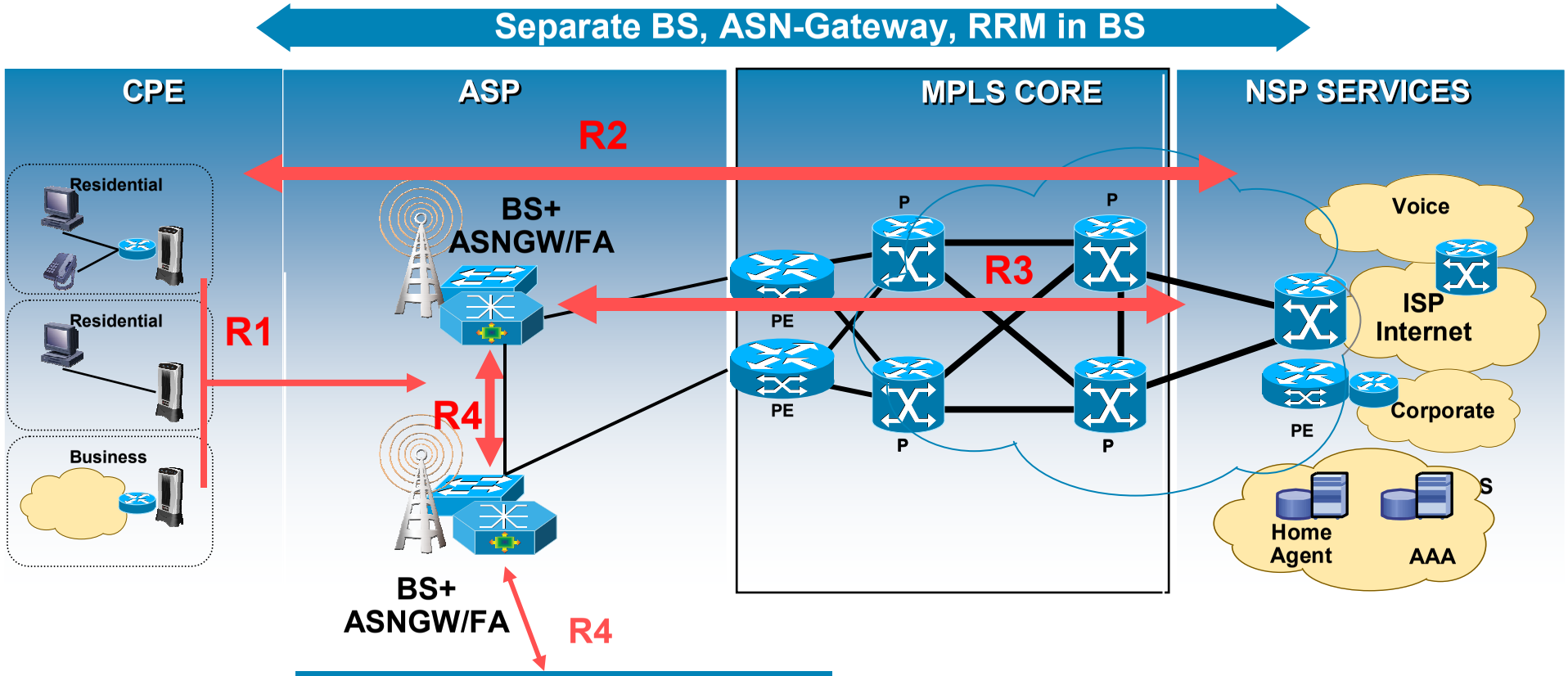
ASN Profile A

BS	ASN-GW
- HO - Data Path 1 & 2 - Authentication Relay - Paging Agent - Key Receiver - Context - RRA - SF Management	- HO - Data Path 1 & 2 - Authenticator - Key Distributor - Context - RRC - SF Authorization - DHCP Proxy/Relay - MIP FA - Location Register - PMIP Client - AAA Client - Paging Controller

R6

R3

ASN Profile B –
no future development



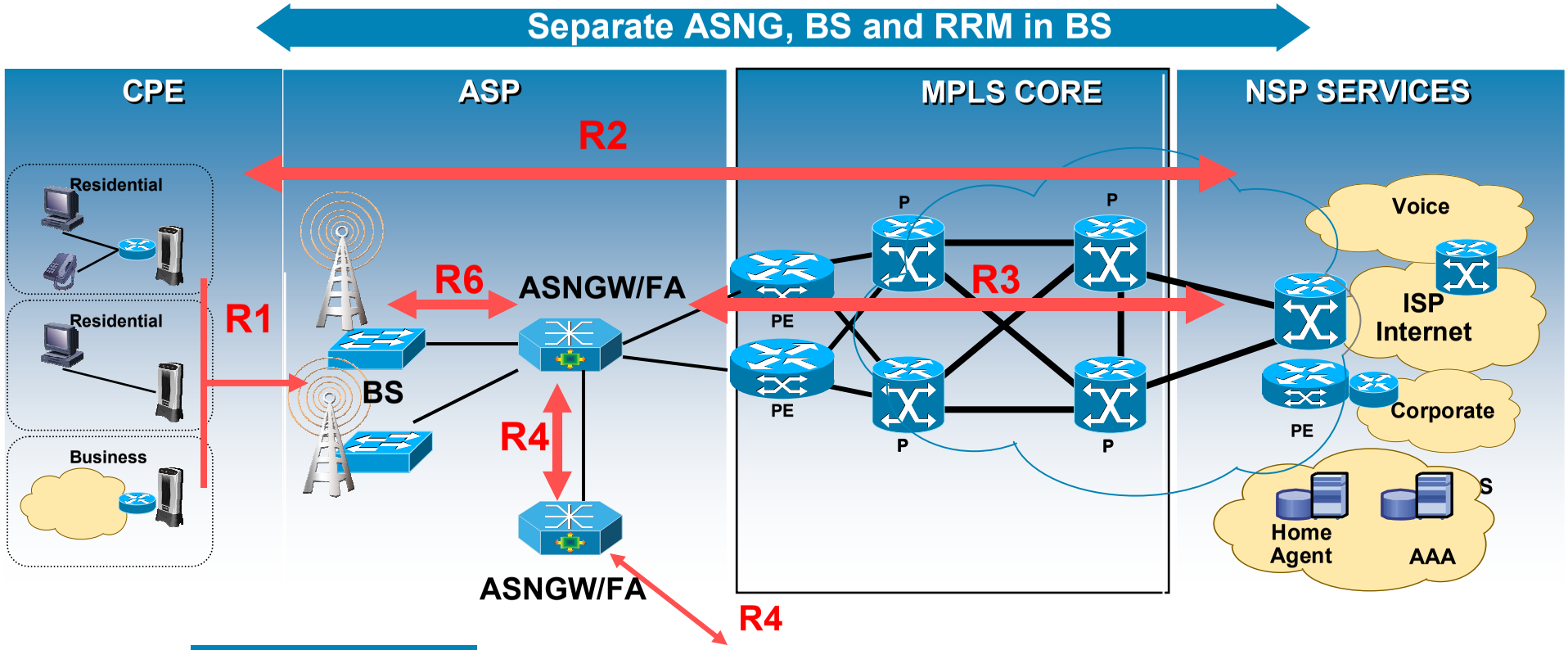
ASN Profile B

- HO
- Data Path 1 & 2
- Authenticator
- Key Rec. &Dist.
- Context
- RRA + RRC
- SF Auth & Mgt

- DHCP Proxy/Relay
- MIP FA
- Location Register
- PMIP Client/Assist
- AAA Client

R3

ASN Profile C -
approved and current development



ASN Profile C

BS
- HO
- Data Path 1 & 2
- Authentication Relay
- Paging Agent
- Key Receiver
- Context
- RRA + RRC
- SF Management

R6

ASN-GW
- HO
- Data Path 1 & 2
- Authenticator
- Key Distributor
- Context
- SF Authorization
- DHCP Proxy/Relay
- MIP FA
- Location Register
- PMIP Client
- AAA Client
- Paging Controller

R3

Profile Comparison

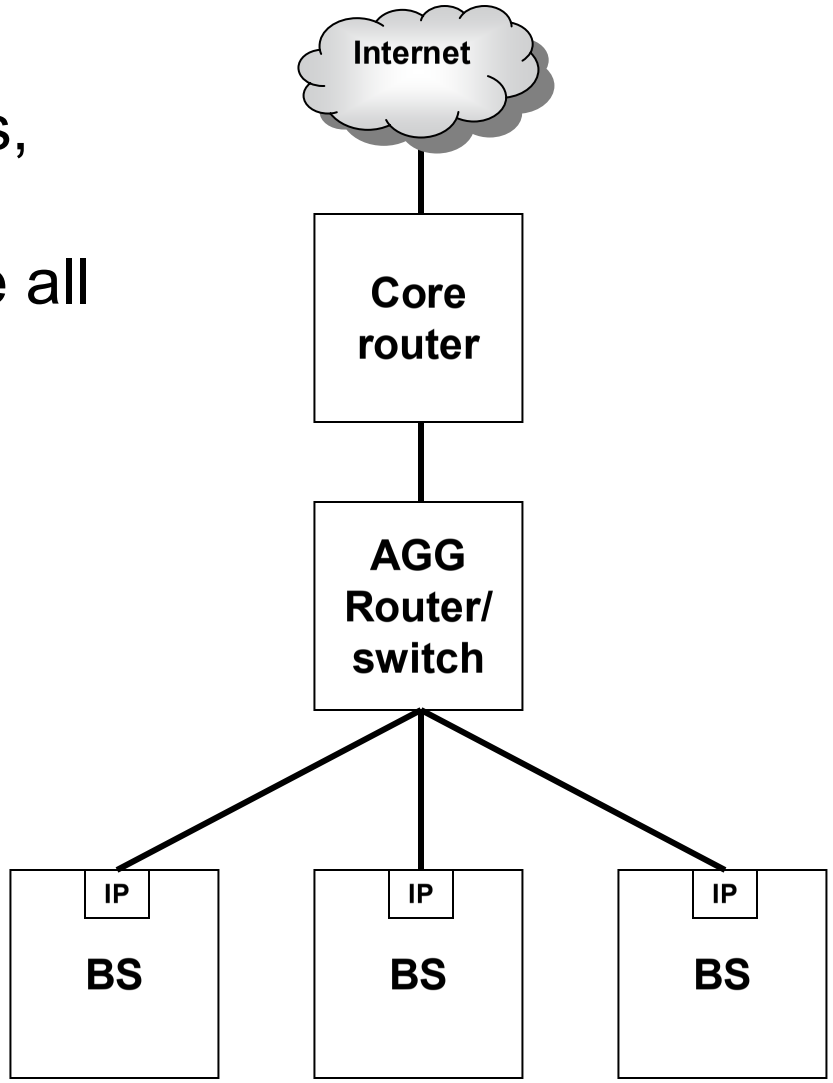
ASN Profile	Description	Pro	Con
Profile A (Deprecated)	Centralized platform Separate BS and ASNGW Split RRM: RRA at BS and RRC at ASN-GW PHY and partly MAC in BTS Handover-Control (RRM) in ASN-GW. Routing and AAA/Paging in ASN-GW	Able to provide simplified pico-cell Able to provide soft handover Fewer backhauls for RRM messages	Difficult Interoperability between BS and ASNGW from different vendors Heavy workload at ASN-GW Fewer vendors
Profile B (No further Development)	Distributed platform Combined BS and ASNGW BS anchored by standard router Inter-BS control over Ethernet	Simple architecture Suitable for small-scale deployment	Difficult to customize IP and wireless functions for operators Expensive for large scale deployment
Profile C (Standards Track)	Distributed platform Separate BS and ASNGW All RRM functions in BS Handover-Control (RRM) in BS Routing and AAA/Paging in ASN-GW	Able to provide simplified pico-cell Open – multi -vendors can supply BS and ASNGW	Extra backhauls for RRM messages

“Mobile” Context & Industry Timing

- Fixed wireless – assumes an externally mounted antenna or a modem in the home and AC power
- Nomadic -- Very much the WiFi experience of carrying your laptop around and logging-in again every time you move
- Portable – Pedestrian speed mobility (<5 mph)
- Simple mobility – Lower speeds (<60 mph) and slower handoffs (>1 sec)
- Full mobility – High speed

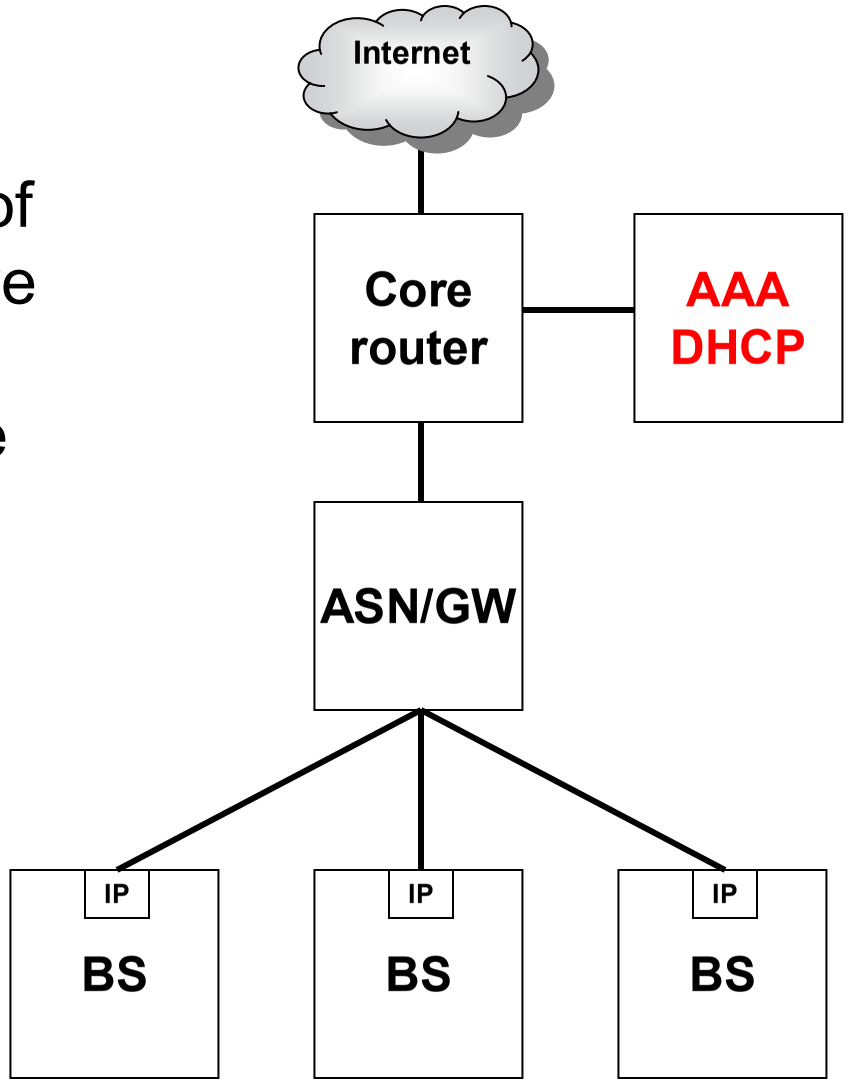
Migration – Fixed

- Fixed addresses,
- No mobility
- Access could be all layer 2



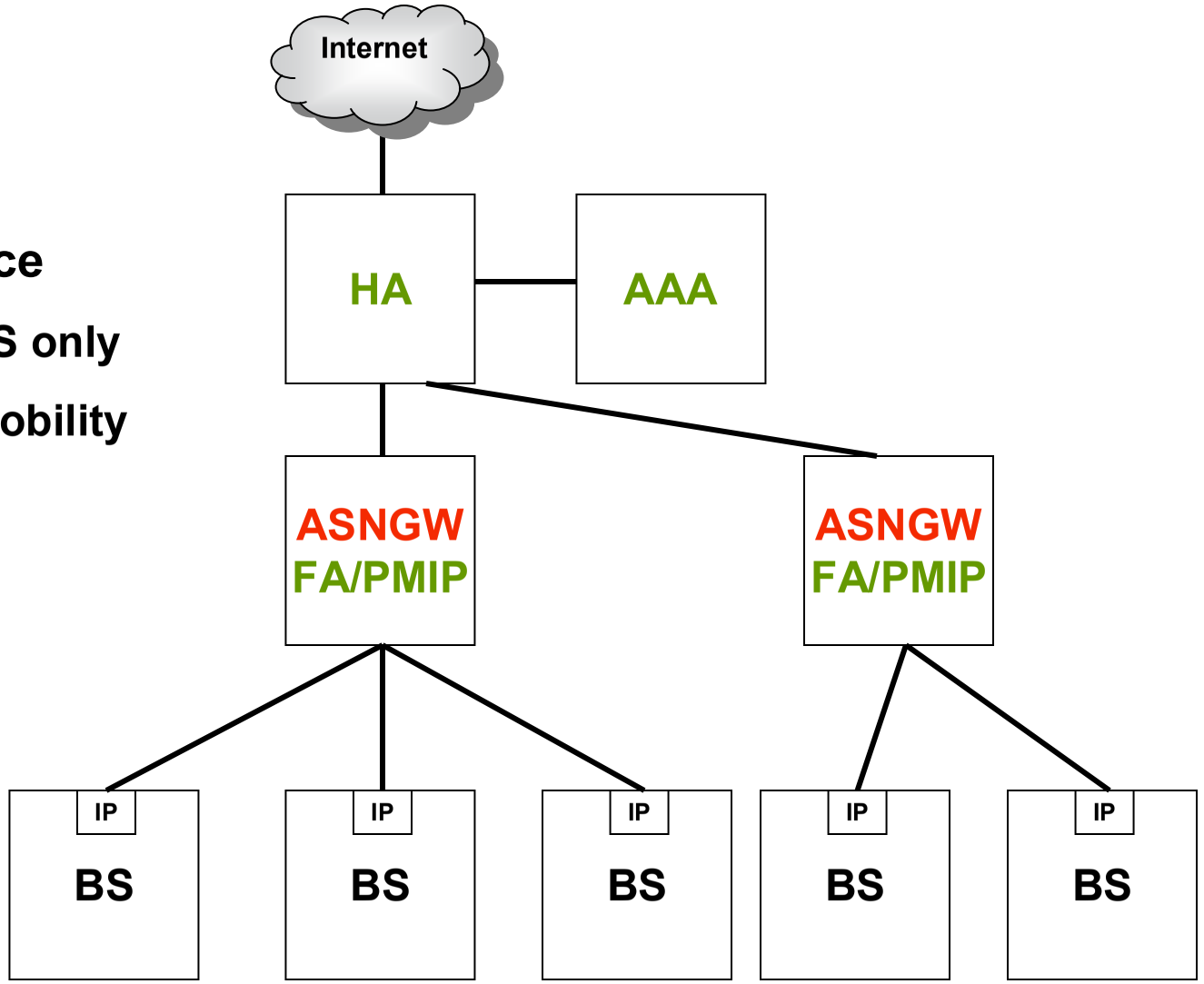
Migration – Fixed/Nomadic

- Add DHCP and AAA, for ability of end user to move and reconnect
- Access could be all layer 2 or IP



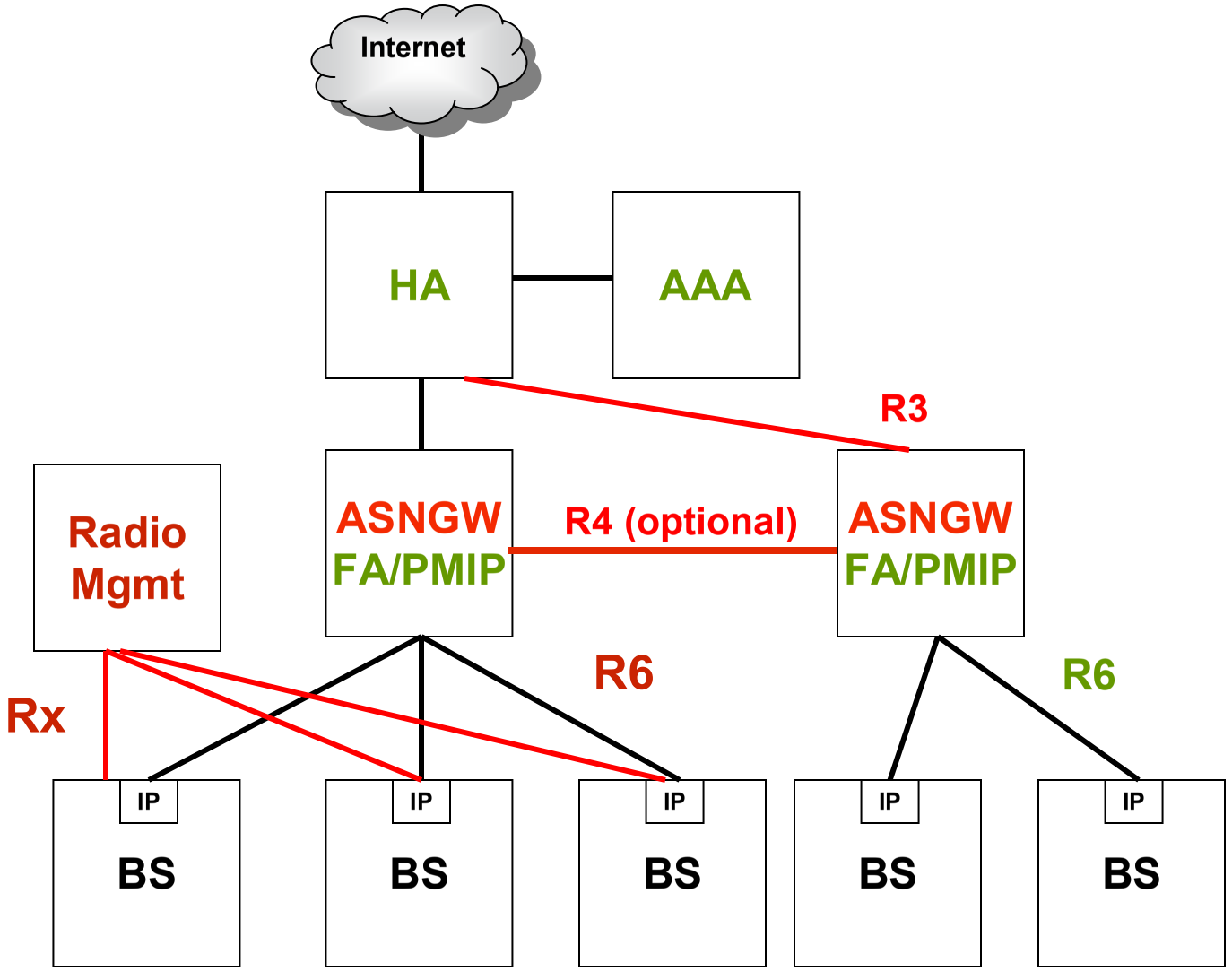
Migration – Mobility (2008)

- Adds MIP
- Basic R6
- Radio Independence
  - Functionality at BS only
  - no RRM for fast mobility



Migration – Full Mobility (2009)

- Adds WiMAX Forum standard interfaces
  - R4 for Inter FA handoff
  - R6 for micro mobility
  - Rx for RRM interface
- Radio Independent Functionality
- Policy support
- Dynamic service flow creation
- Multicast
- VoIP

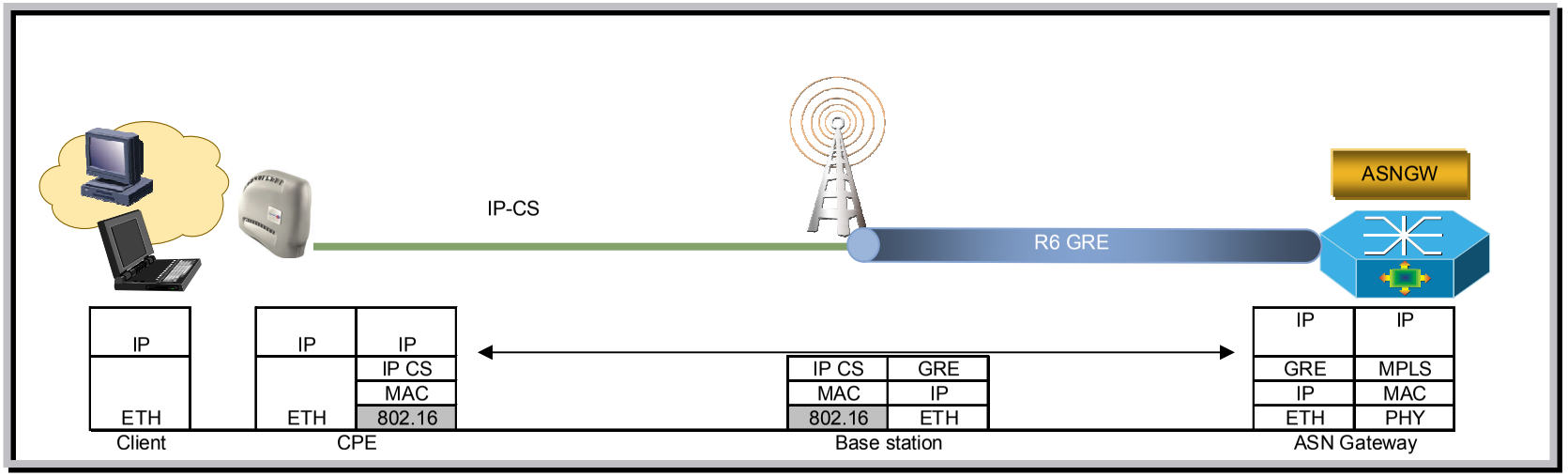


WiMAX Convergence Sub-layers
Optimized for Service Delivery

- **IP-CS (Simple IP)**
  - **Stationary/Nomadic/Portable** usage model
  - R6 Bearer path terminates at the ASNGW for policy enforcement
  - Dynamic SF to meet application SLA
  - Intra-ASN Mobility
- **IP-CS (PMIP)**
  - **Mobile** usage model
  - Bearer path terminates at the HA for policy enforcement
  - Inter-ASN Mobility
- **Ethernet-CS**
  - **Stationary/Nomadic/Portable** usage model
  - Centralized control plane via ASNGW
  - Bearer path terminates at BS (decoupled from R6)
  - Interworking with Carrier Ethernet for Ethernet Services

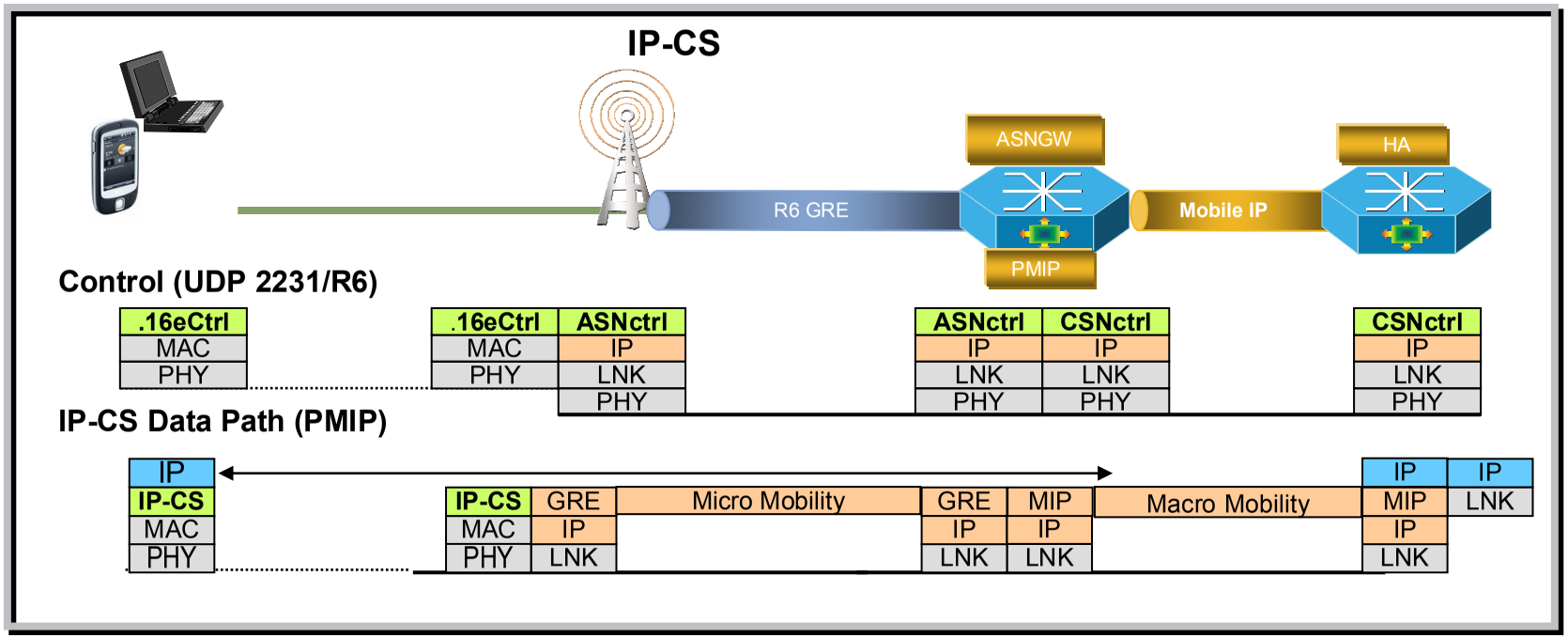
WiMAX IP-CS
(Simple IP)

- R6 User-Plane based on GRE between BS and ASN GW
- R6 Control Plane handles Authentication, SF Assignment, etc
- SF Session per user uniquely identified through GRE-Key
- GRE to VRF at ASN GW for service separation
- Targets Residential and Nomadic model plus managed Voice



WiMAX IP-CS
(PMIP)

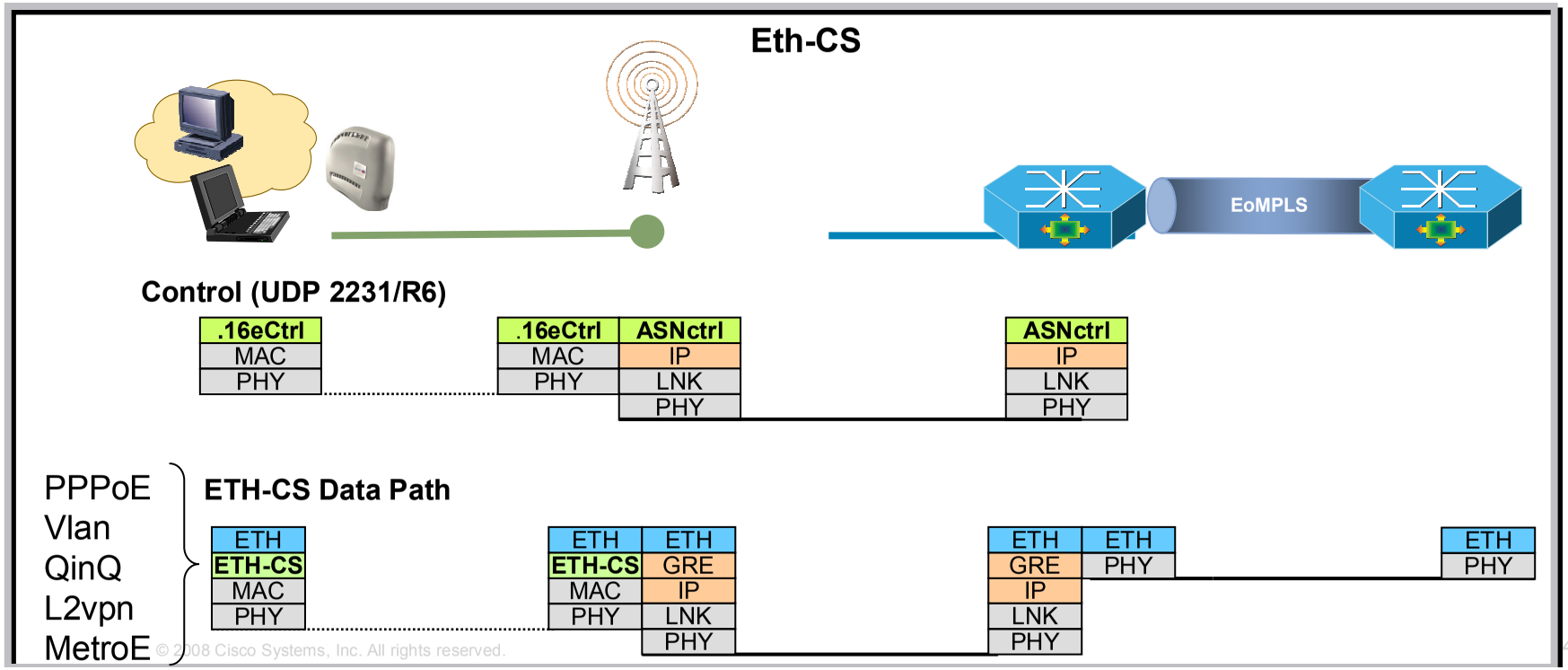
- R6 Control Plane handles Authentication, SF Assignment, etc
- SF Session per user uniquely identified through GRE-Key
- PMIP Client and FA embedded in ASN GW
- HA is the Local Mobility Anchor (LMA)



WiMAX Ethernet-CS

Control Plane de-coupling (Future..)

- Decouples the Bearer Path from R6 (local breakout at BS)
- R6 Control Plane handles Authentication, SF Assignment, etc
- Service Interworking with Carrier Ethernet
- Enables Integration with DSL TR-101 (V-Interface)
- Avoids turning the ASN GW into L2 bridge
- Targets business and wholesale model



WiMAX 802.16 Service Flow
Model Definitions

- Packets are associated with a service flow, which is the central concept of the MAC protocol
- *Service flow* = an unidirectional flow of packets with a particular QoS
- Service flow has parameters like bandwidth, latency, jitter and other QoS-related variables
- When data comes to MAC layer, the convergence sublayer gives it an connection ID (CID)
- The service flow is mapped to this ID {CID,SFID}
- The Service Flow ID is fixed across Base-Stations. Each Base-Station maps a SFID to a new CID.
- Created on-demand or pre-provisioned

  On-demand SF creation subject to authorization against permitted QoS parameters

WiMAX QoS & Scheduling Schemes

Specifications & Applications…

QoS Category	Applications	QoS Specifications
UGS Unsolicited Grant Service	VoIP	•Maximum Sustained Rate •Maximum Latency •Jitter Tolerance
rtVR Real-Time Variable Rate Service	Streaming Audio or Video	•Minimum Reserved Rate •Maximum Sustained Rate •Maximum Latency •Traffic Priority
ErtVR Extended Real-Time Variable Rate Service	Voice with Activity Detection (VoIP)	•Minimum Reserved Rate •Maximum Sustained Rate •Maximum Latency •Jitter Tolerance •Traffic Priority
nrtVR Non-Real-Time Variable Rate Service	FTP File Transfer Protocol	•Minimum Reserved Rate •Maximum Sustained Rate •Traffic Priority
BE Best-Effort Service	Data, Web Browsing, etc.	•Maximum Sustained Rate •Traffic Priority

- **Service Flows**:

  Mechanism defined in Mobile WiMAX to provide QoS

  Uni-directional flow of packets associated with certain defined QoS parameters for traffic

- **Connections:**

  Unidirectional logical link between BS and CPE

  Each connection is associated with a service flow delivering the necessary QoS over the air interface

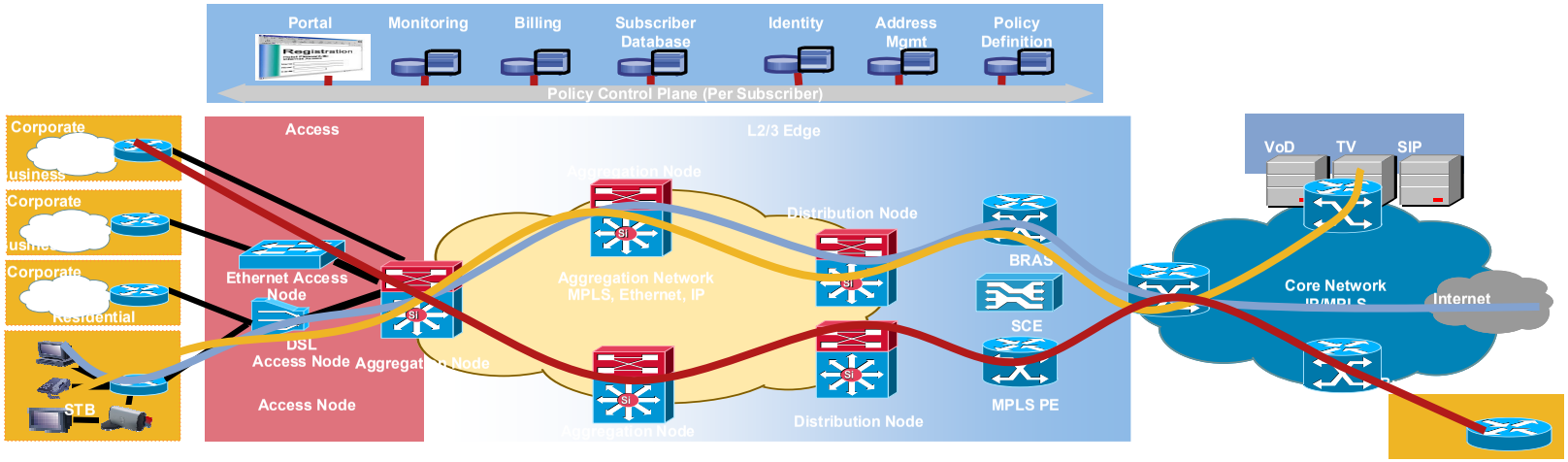
- **Packet Classifiers:**

  Each service flow also has packet classifiers associated with it to determine criteria used by the MAC layer to associate packets into service flows

- Mobile WiMAX scheduling based on QoS service Flows associated with each packet

WiMAX Solution QOS

Architecture using IP-NGN



Consumer and Business Traffic Utilize Per-Subscriber or Per Service QoS Model in Access, Aggregation and Core

Traffic Class	Core /Edge/ Aggregation			Access	UNI		
	MPLS/IP			Ethernet	DSL, ETTX	DSL	**WiMAX**
	PHB	DSCP	MPLS EXP	802.1P	802.1P	ATM	**802.16**
Control Protocols Network Management	AF	48	6	(6)	(6)	VBR-nrt	**nrtPS**
Residential Voice	EF	46	5	5 and 7	5 or 7	VBR-rt	**rtPS**
Business Real-time	EF	56	7				
Residential TV and VoD	AF	32	4	4 and 3	4	VBR-nrt	**NA**
Residential D-Server Video	AF	24	3				
Business Critical In Contract Business Critical Out of Contract	AF	16 8	2 1	2 and 1	2 1	VBR-nrt	**nrtPS**
Residential HSI Business Best Effort	BE	0	0	0	0	UBR	**Best Effort**

Cisco WiMAX Solution
ASN-gw QoS Models

- Pre-Provisioned Service Flow:

  Profile Downloaded from AAA at registration may indicate number of pre-provisioned service flows, and/or default behaviour (e.g: default service flow)

  A service flow request initiated by the MS or BS is evaluated against the provisioned information, and the service flow is created if permissible

- Dynamic Service Flow :

  Triggered by the network with Application Function Interaction

  – External Application Function

  MS initiated based on classification policy

WiMAX Solution Security and Authentication
Framework Overview…

- **PKMv2 Framework**

  Mobile WiMax uses the Privacy and Key Management Protocol Version 2 (PKMv2) to manage all security, authentication and encryption schemes over the air interface

  PKMv2 manages AK security using PKM messaging between BS and CPE

- **Device and User authentication:**

  User authentication in Mobile WiMAX is done using EAP authentication schemes.

  Navini Mobile WiMAX solution supports EAP-TLS, EAP-TTLS and EAP-AKA etc

  Device authentication done using X.509 certificates in WiMAX CPE

- **Traffic Encryption:**

  Traffic encryption using 128 bit AES encryption scheme

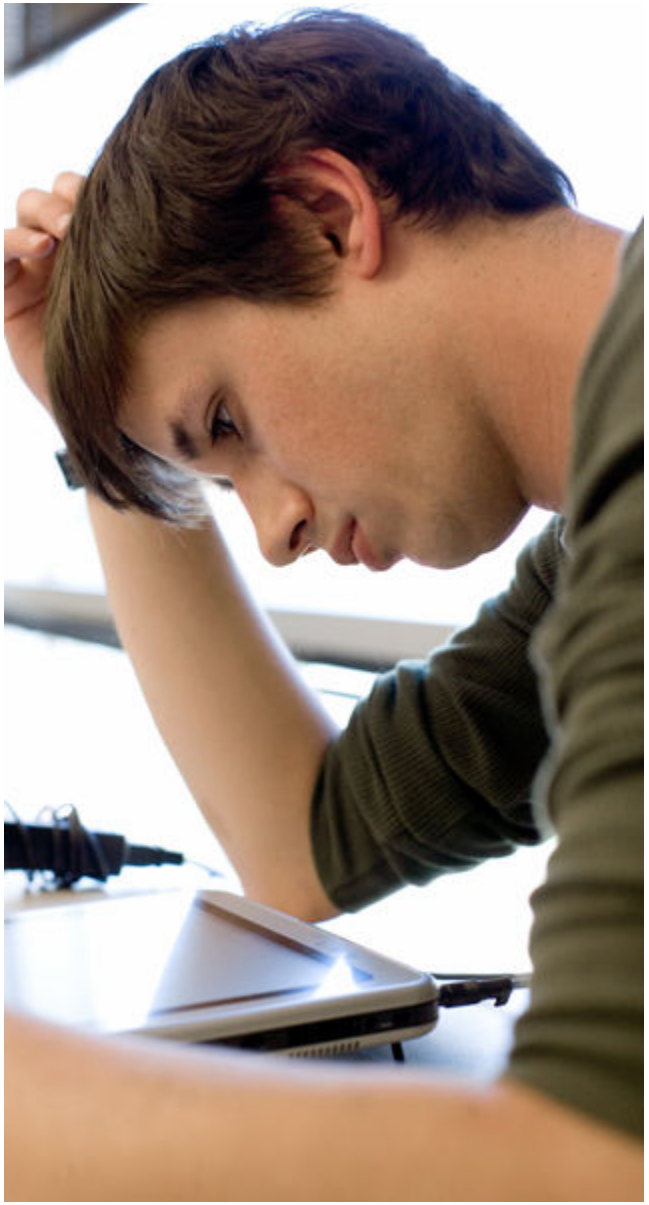
  AES encryption keys derives from EAP authentication and transported over PKMv2 framework

- **Security context and associations:**

  All security and encryption contexts and associations maintained over mobility events and other network events

Agenda

- WiMAX Introduction
- WiMAX Forum Update
- Radio Interface
- Core Architecture
- **Cisco WiMax Products**
- Q & A



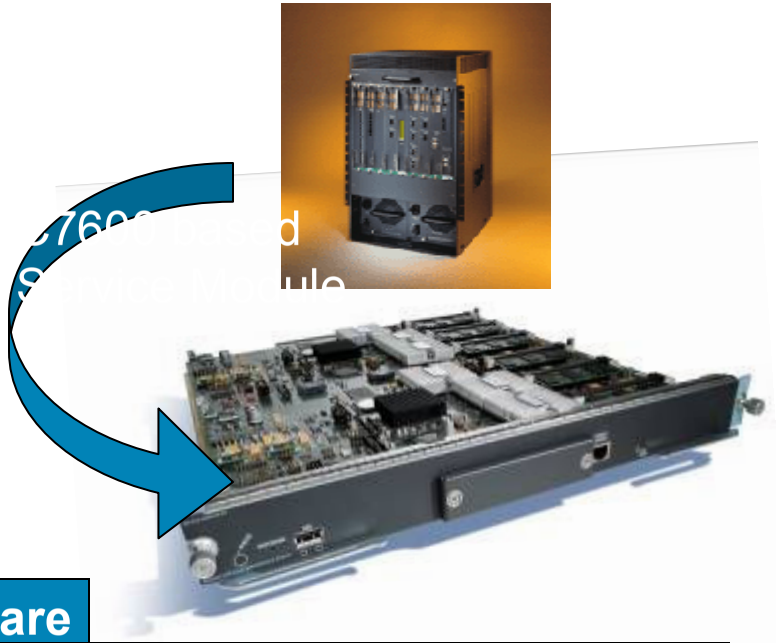
Cisco ASNgw Overview

Architecture

→**Carrier Class Features**

- ASNgw Clustering using ASNgw-SLB
- Geographic Load Balancing & Scaling
- Stateful 1:1 Redundancy

- Deep Packet Inspection & Accounting
- Carrier-grade billing support using CSG2 (pre & postpaid)



Scaling

→**Carrier Class Performance**

- 8 Gbps per card using IMIX packet
- 100K Subscribers, 30% active, 70% idle
- Unlimited # of sessions per Subscribers

A smaller "standalone", 1RU high appliance based ASN-gw based on C7301 is available for Field/Demo trials

Software

→**Release 1 Features**

- Authentication/Security
- QoS
- Mobility (micro)
- IP address allocation
- Initial Network Entry of a user
- Service Flow creation for a user (with only pre-provisioned service flows)
- De-registration of a MS
- Support for unpredicted Hard Handoff
- Support for IP Convergence sublayer (CS) only

What is Cisco Acquiring?
Advanced WiMAX Broadband Wireless BTS & CPE

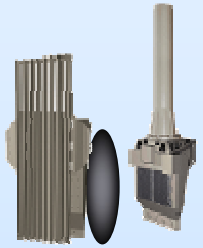
Navini provides Cisco with a full-range, industry-leading portfolio of IEEE 802.16e-2005 compliant products and technologies

RipWave® MX BTS MX

- Software upgradeable for WiMAX 802.16e-2005 Wave 2 certification
- Unmatched radio link budgets
- First to support WiMAX Advanced Antenna Systems (AAS) for Beam-Forming

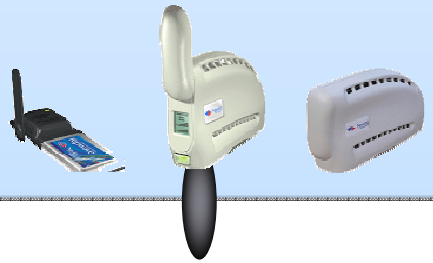
RipWave® MX Antenna Systems

- Multi-antenna configuration for beam-forming and MIMO
- Omni-directional and sector configurations
- Market-leading gain, reliability and availability

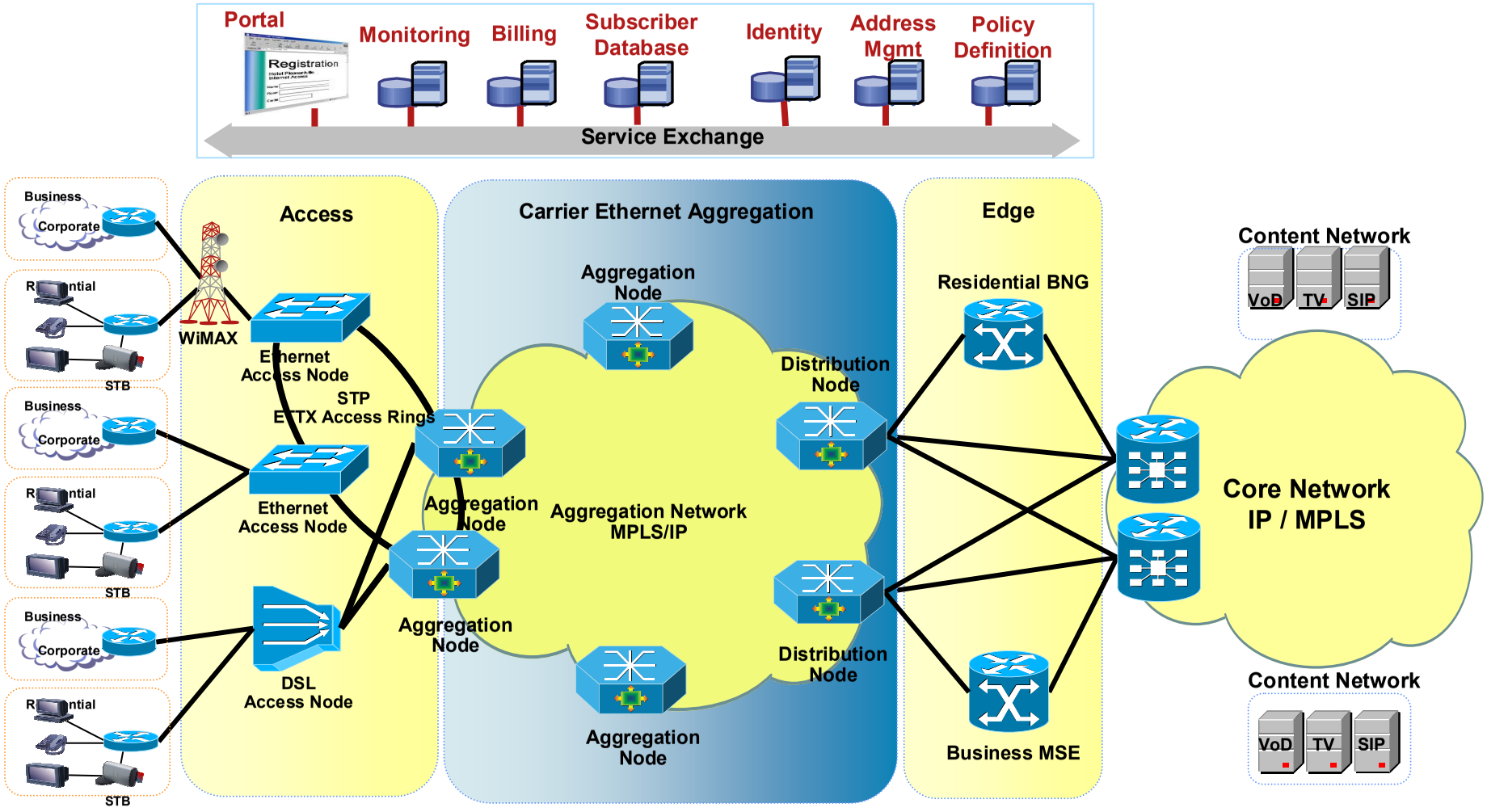


RipWave® MX Customer Premise Equipment

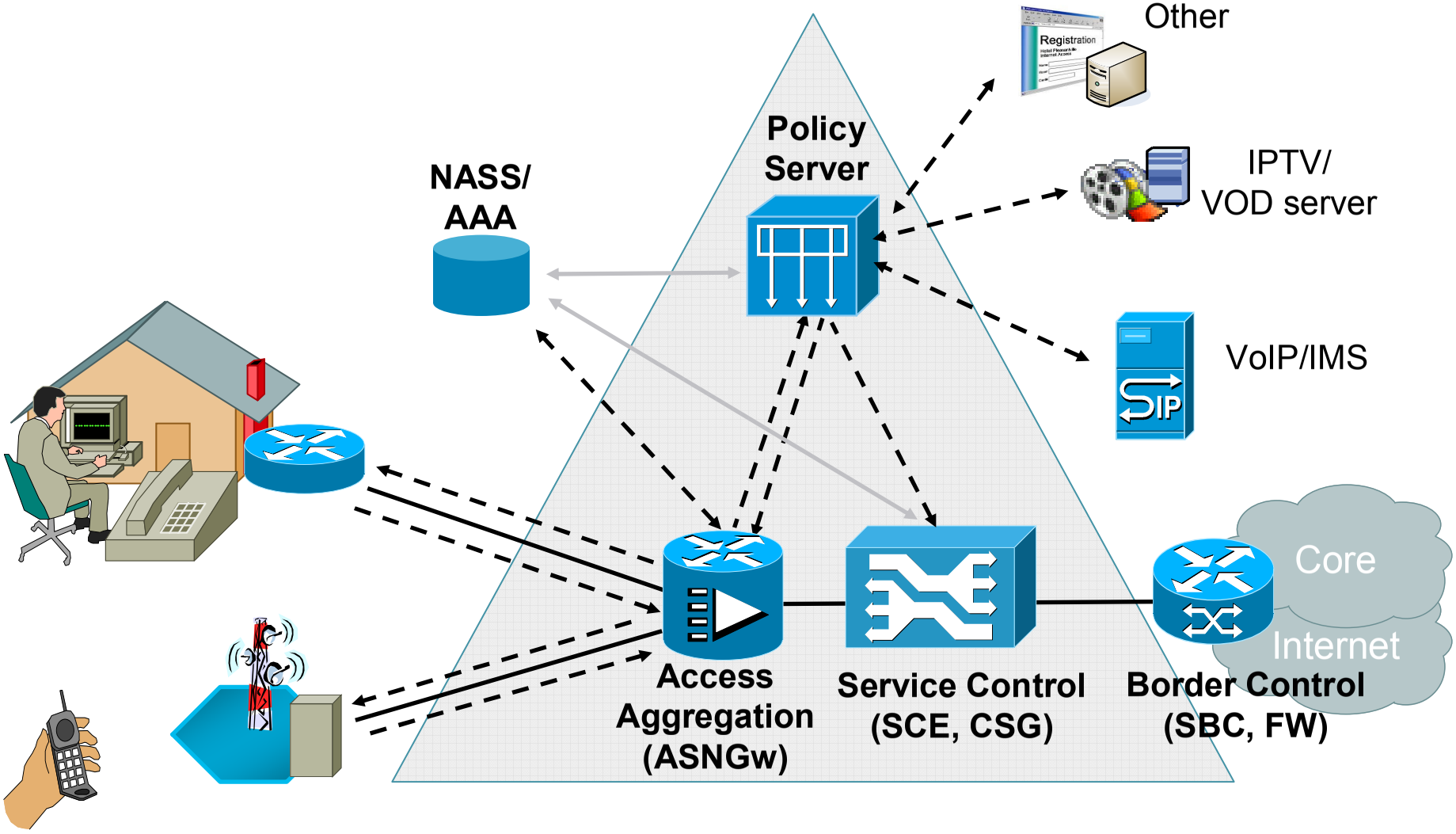
- Zero-install, plug-and-play portable/mobile operation
- Sleek, appealing retail-friendly design
- Over-the-air activation



Carrier Ethernet Aggregation System

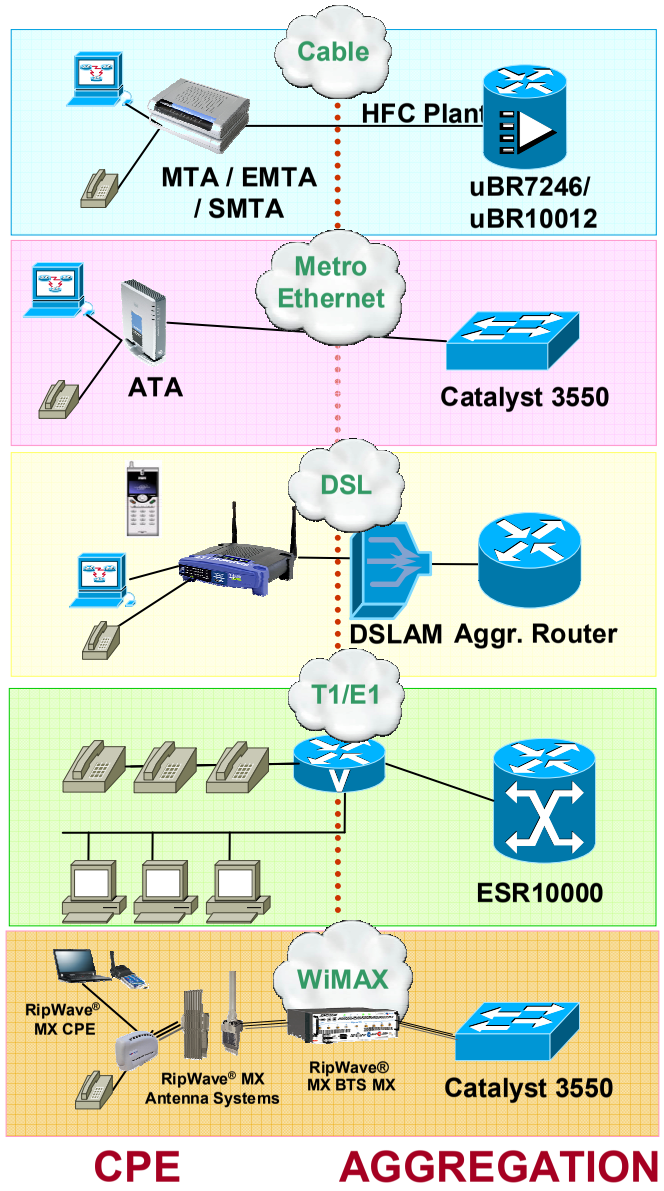


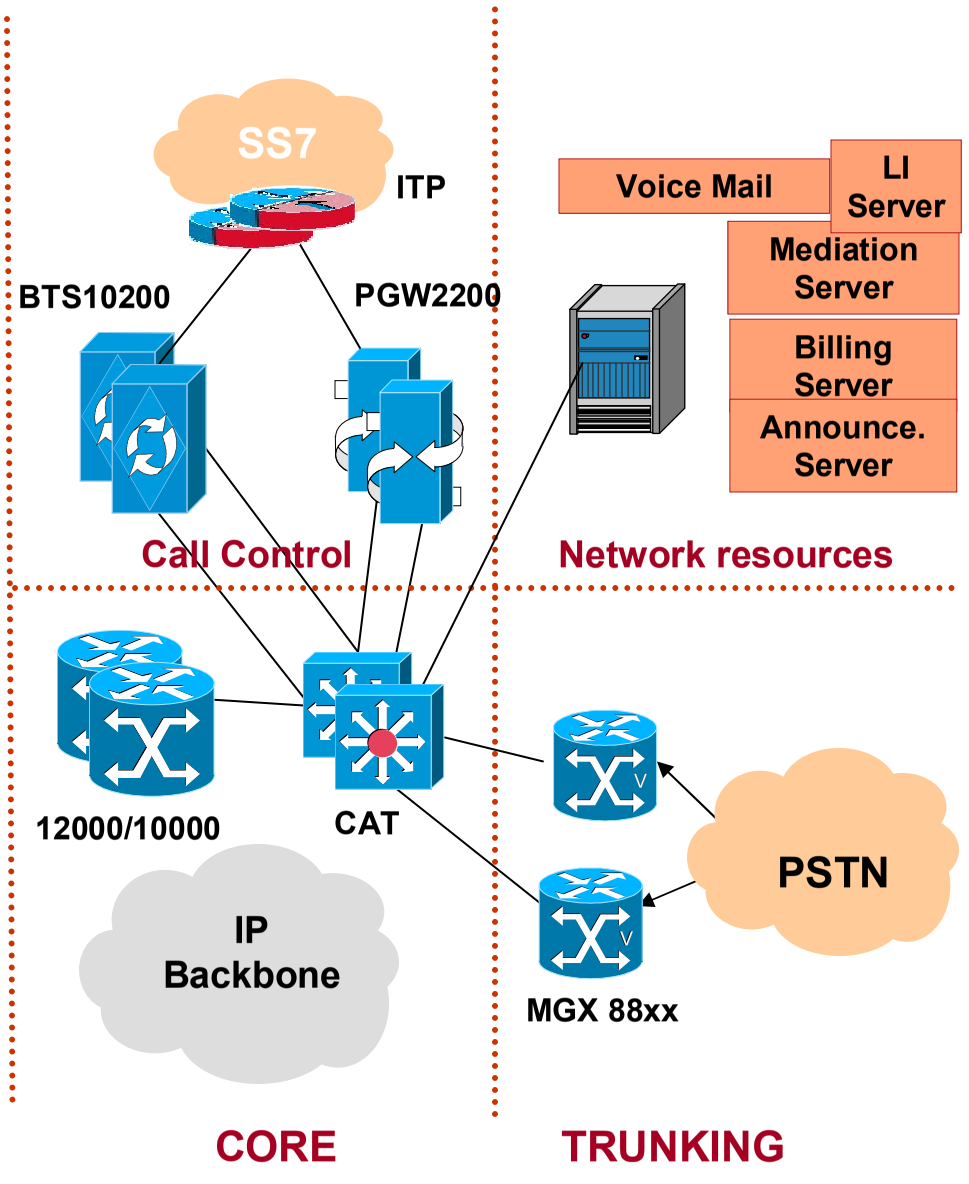
The SEF Building Blocks



Cisco Softswitch Solutions

Broadband VoIP Residential & Business Services





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