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ETSI Standards for Broadband Radio Access Networks (BRAN)

Bernd Friedrichs
- Marconi Communications, Germany
- ETSI BRAN Chairman

Overview

- **ETSI BRAN project**
- **Benefits of Standards**
- **HiperAccess**
- **HiperMAN**
- **ETSI testing**
- **Technical Annex**

About ETSI
(European Telecommunications Standards Institute)

- **699 members**
  from 55 contries in five continents (manufacturers, operators, service providers, administrations, research bodies, users)

- **~10,800 technical standards and deliverables**
  produced in period 1988 - 2002

- **~60 co-operation agreements**
  between ETSI and other bodies

- **Market driven organization**
  members decide about work program and resource allocation,
  ➔ ETSI activities/products closely aligned with market needs

- **Established in 1988**, as non-profit making organization, based in Sophia Antipolis (France)

ETSI Working Methods

Decision Making

- Members shall endeavour to reach consensus on all issues.
- If lack of consensus: voting can be performed using individual member weights (1...45). Approval requires 71% of the votes.

Open Standardization Process

- Each ETSI member can actively or passively participate (incl. voting).
- All documents are always freely accessible.

IPR Policy

- Each ETSI member has the obligation to inform about Essential IPRs it becomes aware of.
- IPR owners shall grant irrevocable licenses on fair, reasonable and non-discriminatory terms and conditions.

About BRAN
(Broadband Radio Access Networks)

- ETSI Project (EP) BRAN established in 1997
- In response to growing market pressure for low-cost, high-capacity broadband radio systems
- Fixed Wireless Access (FWA) systems as competitive alternatives to wireline access systems with
  - high performance (QoS, spectral efficiency)
  - flexibility
  - easy to set up
- Interoperable standards
- BRAN assists (via ETSI ERM RM) regulatory bodies to define spectrum requirements and radio conformance specifications for new broadband radio networks

ETSI BRAN Interoperable Standards

ETSI Project BRAN
(Broadband Radio Access Network)

Chairman: Prof. Dr. Bernd Friedrichs (Marconi)

- **HiperLan/2** (High Performance LAN)
  Wireless LAN at 5 GHz, connection-based, 54 Mbps, QoS
- **HiperAccess** (High Performance Access)
  Fixed broadband wireless PMP system above 11 GHz, based on single carrier
  - **PHY** physical layer
  - **DLC** data link control layer
  - **CL** convergence layers
  - **Testing** radio & protocols
- **HiperMan** (High Performance MAN)
  Fixed broadband wireless PMP system below 11 GHz, based on OFDM

BRAN History

- **HiperLAN2 (HL)**
  - Initial considerations started 1997
  - PHY layer harmonization with IEEE802.11a in 1998
  - Base specs published in 2000
  - Fine-tuning of specs, testing and work on extensions ongoing
- **HiperAccess (HA)**
  - Initial considerations started 1998
  - Fundamental decisions (interoperable, architecture) in 1999
  - Base and test specs published in 2002
  - Fine-tuning of base and test specs ongoing, harmonization with 802.16
  - Harmonized Standard (HEN) expected for 2004
- **HiperMAN (HM)**
  - Initial considerations started 2001
  - Base specs published in second half of 2003
  - Test specs expected for 2004/2005
  - Extensions under discussion

BRAN Meetings

More than 50 meetings (regular and interim) since April 1997, typically attended by 35...100 persons, very often at ETSI HQ in Sophia Antipolis (France), but also at other locations around the world, including

- **Finland** (Tampere, Helsinki)
- **France** (Rennes)
- **Germany** (Ulm)
- **Greece** (Athens)
- **Italy** (Stresa)
- **Japan** (Tokio)
- **Netherlands** (Eindhoven)
- **Sweden** (Stockholm)
- **Turkey** (Istanbul)
- **UK** (London, Great Chesterford)
- **US** (Orlando, Washington, San Diego)
- **etc. (Working Group meetings)**

BRAN Relationship with Other Bodies and Forums

- **IEEE 802 (see extra slide)**
- **WiMAX (see extra slide)**
- **ITU (ITU-R, ITU-T, ITU-D)**
- **ETSI (OCG, TM4, ERM)**
- **CEPT** (European Conference of Postal and Telecomm. Administrations)
- **CITEL** (Inter-American Telecommunications Commission of the OAS)
- **3GPP** (3rd Generation Partnership Project)
- **H2GF** (HiperLAN2 Global Forum)
- **ATM Forum**
- **IETF** (Internet Engineering Task Force)
- **MMAC-PC** (Multimedia Mobile Access Comm. System Promotion Council)

Harmonization BRAN - IEEE 802

	IEEE 802	ETSI BRAN	Remark
WLAN promotion:	802.11a WiFi	HiperLAN2 H2GF	same PHY layer
WMAN	**802.16 (10-66 GHz)**	**HiperAccess**	same PHY layer, further harmonization intended (TC layer, protocol stack)
	802.16 (2-11 GHz) (mobile extension)	**HiperMAN** (restricted to fixed operation)	interoperability on subset (OFDM)
promotion:	**WiMAX**		formal co-operation agreement expected soon
WPAN	802.15	currently no activities	
MBWA	802.20	mobile extension for HM tbd.	
Roaming	802.21	currently no activities	

Co-operation ETSI - WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) mission:

- Promotion of BWA systems (operating between 2.5 and 66 GHz)
- Certification of interoperability for products from multiple vendors

ETSI and WiMAX have a common interest

- to perform and promote standardization with the aim of a global information infrastructure
- in avoiding duplication of technical work

ETSI and WiMAX co-operate for profiling, testing and certificating of

- HiperMAN (and for further enhancements to HM)
- HiperAccess (if HA and WirelessMA-SC closer aligned)

WiMAX will use with permission

- conformance test specifications developed by ETSI BRAN
- expertise of ETSI PTCC
- ETSI Plugtest™ service for interoperability events

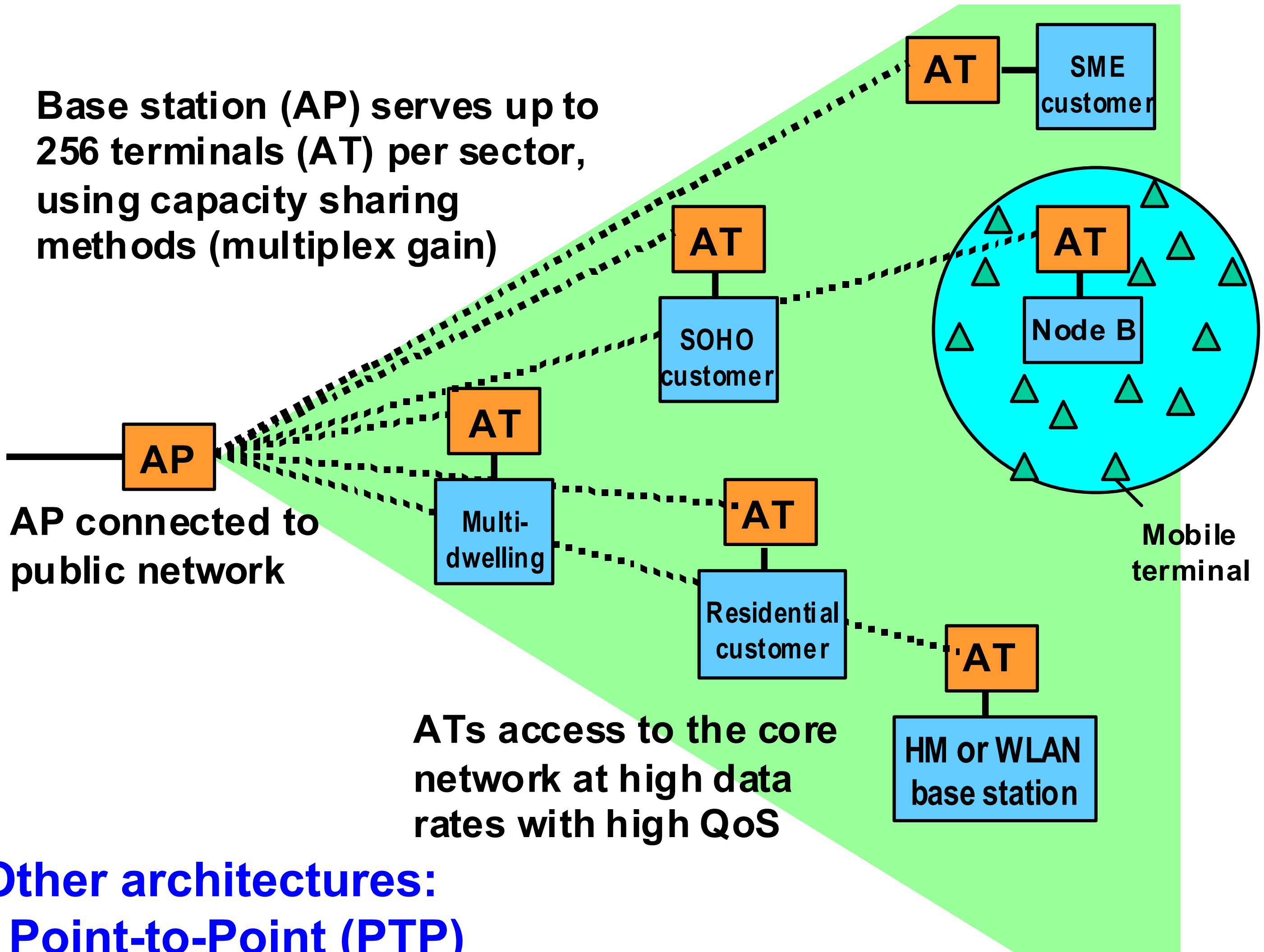
Advantages of Standards

- The **world wants standards** for all telecommunication areas (obvious for mobile systems, but even for fixed systems)
- Standards (together with promotion activities) **push the market** (today the market for wireless access is still in early stage)
- Active participation of operators and manufacturers in BRAN
  ➔ optimized for important applications
  ➔ optimized for low-cost and high performance
  (critical for competiton with wireline access)
- **Main advantages** of an interoperable standard
  ➔ large volume ➔ low cost
  ➔ increased competition between vendors ➔ low cost
  ➔ co-operation between vendors possible ➔ low cost
  ➔ customers can compare, so more choice in access
  ➔ operators have quick and economic access to users

Overview: HiperAccess (and HiperMAN)

- **Point-to-Multipoint (PMP)** topology
- **Interoperability** (testing is normative part of standard)
- Standard allows for **vendor-differentiated** products, e.g.,
  - management,
  - core network interfaces,
  - ARQ,
  - broad range of cellular constellations
  - security,
  - bandwidth allocation strategies, ...
- **Spectrum efficient** (both for IP and ATM core networks)
- **Dramatic improvements** compared to 1G/proprietary systems
- **Interest in HA from**
  - Manufacturers: Alcatel, Ensemble, Ericsson, Marconi, Nokia, Siemens, ...
  - Operators: France Telecom, Omnitel Vodafone, Sonera, Telecom Italia, Telekom Austria, Telenor, Telia, ...

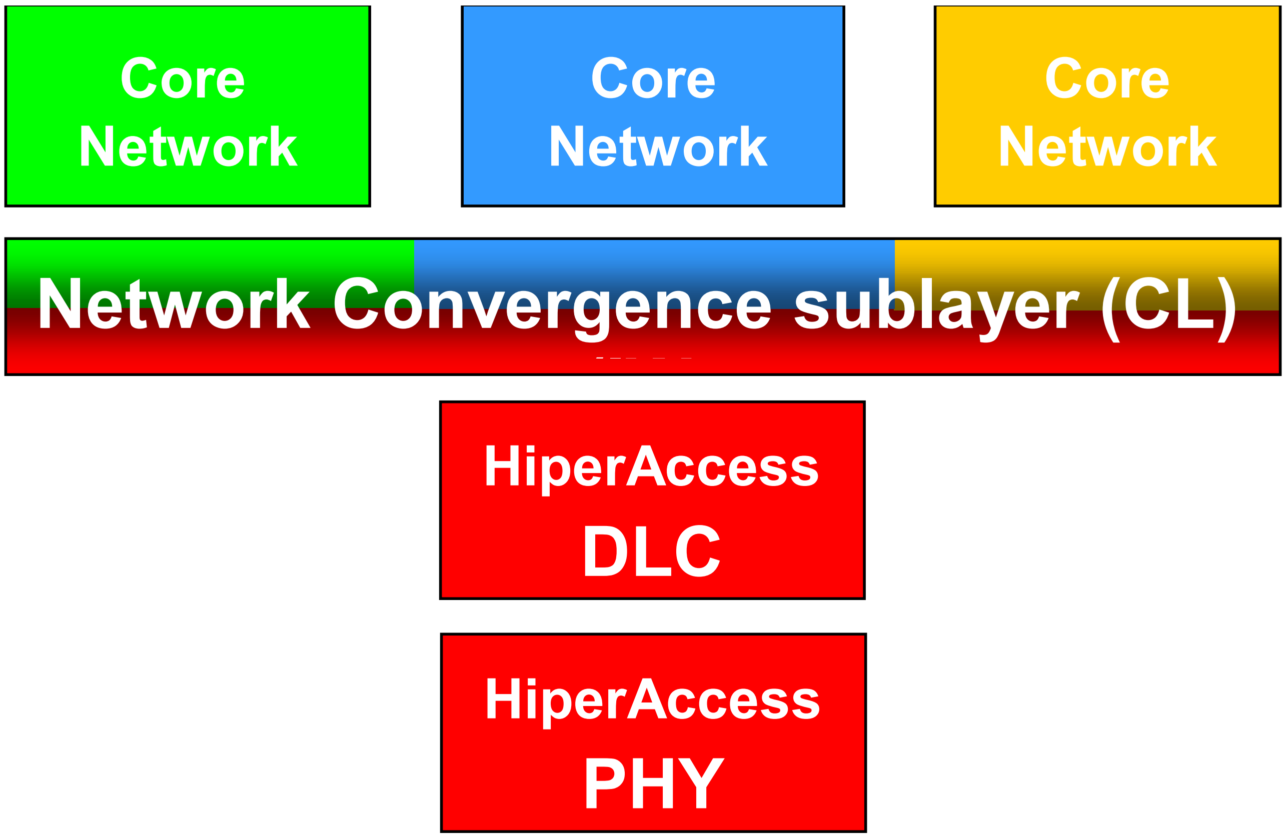
Point-to-Multipoint (PMP) Architcture



Other architectures:

- Point-to-Point (PTP)
- Multipoint-to-Multipoint (Mesh)

Interworking Approach (shown for HA, similar for all BRAN systems)



Core Networks:
ATM, IP, ISDN, PSTN,...

Removes differences between core networks

Matched to the requirements for supporting ATM and IP

Ensure cost-effective implementation and spectral efficiency

DLC and PHY layers are independent of the core network

HiperAccess: Basic Features PHY Layer

Focus on frequency bands

- 40.5 - 43.5 GHz
- 31.8 - 33.4 GHz
- 27.5 - 29.5 GHz
- 24.5 - 26.5 GHz
- other lower frequencies

Channel size = 28 MHz, Baudrate = 22.4 MBaud

- Paired bands (FDD mode, fixed asymmetric rates)
- Unpaired bands (TDD mode, adaptive asymmetric rates)
- Optimum trade-off between costs, peak data rate and statistical multiplex gain

Important parameters

	Downlink (AP $\rightarrow$ AT)	Uplink (AT $\rightarrow$ AP)
Data rates (Mbit/s)	20...120 (typically 80)	20...80 (typically 50)
Transmit power	15 dBm	14 dBm
Range	up to 12 km (hard limit from ranging, effectively depending on availability and rain zone)	

HiperAccess: Adaptive Coding and Modulation

Adaptation

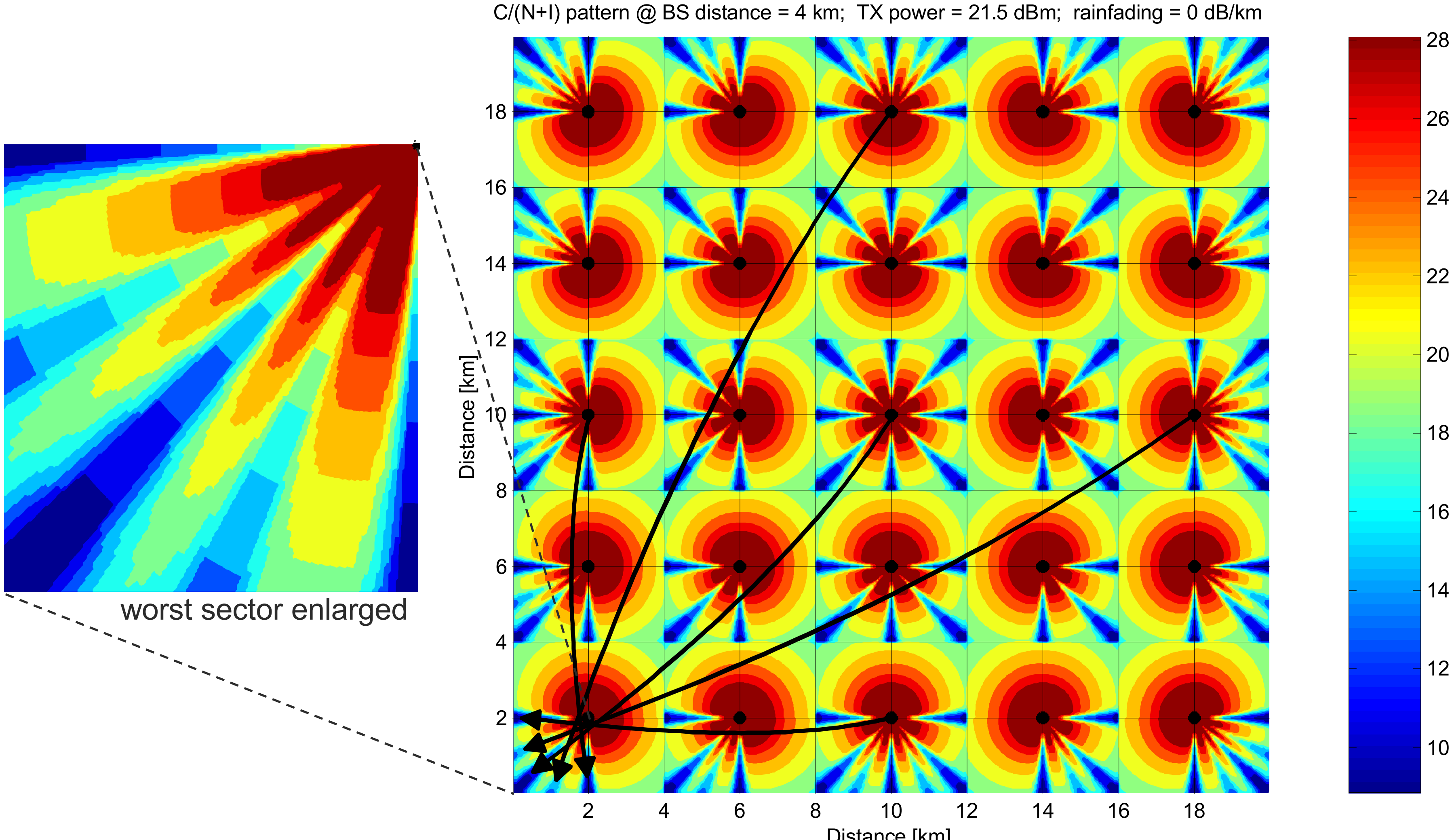
- according to distance
- according to interference
- according to rain fading (20 dB/s)
- per terminal
- per frame
- combined with ATPC (Adaptive Transmit Power Control)

PHY mode defined by modulation and concatenated coding

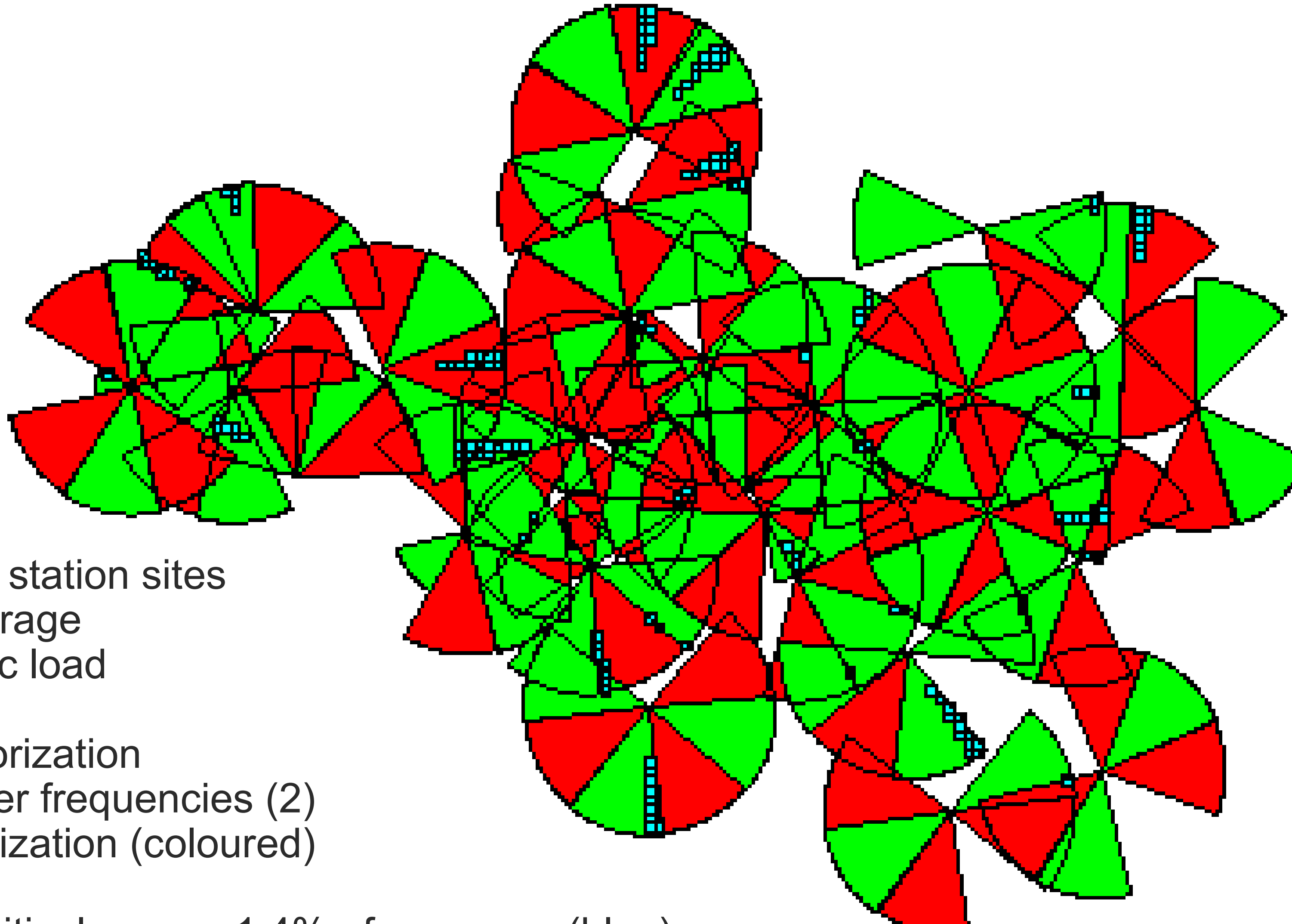
Mode	Modulation	Outer Block Code	Inner Convolutional Code	Information word length	Spectral efficiency	Required C/(N+I)
0 (CZ)	QPSK	RS(t=8)	R=1/2	30 byte	from ~ 0.5 bit/s/Hz to ~ 3.8 bit/s/Hz	7 dB
1	QPSK	RS(t=8)	R=2/3	1...4 PDU		8 dB
2	QPSK	RS(t=8)	-	1...4 PDU		12 dB
3	16-QAM	RS(t=8)	R=7/8	1...4 PDU		18 dB
4	64-QAM	RS(t=8)	R=5/6	1...4 PDU		25 dB

PHY mode set 1

C/(N+I) Pattern for 5x5 Rectangular Constellation (Downlink, ClearSky, ReUseFactor =4)



Marconi's Radio Network Planning Tool (Realistic Constellation with 142 Sectors)



Input: Base station sites
Coverage
Traffic load

Output: Sectorization
Carrier frequencies (2)
Polarization (coloured)

Interference critical zone = 1.4% of coverage (blue)

HiperAccess: Basic Features of DLC Layer

Access scheme

- Downlink: TDM (Time Division Multiplexing)
- Uplink: TDMA (Time Division Multiple Access)

Frame based

- 1 ms frame duration
- Optional adaptive TDD mode (unpaired bands)
- Optional H-FDD terminals (paired bands, separated TX and RX)
- Optional ARQ

Fixed length PDUs

- Efficient support of ATM and IP, robust, high QoS, allows ARQ

QoS Classes

- Constant bit-rate,
- Real-time variable bit rate
- Non-real time variable bit rate
- Best effort

Resource allocation mechanisms

- Continuous grant, polling, piggybacking, random access

HiperMan: Overview

Broadband Fixed Wireless Access (FWA)

- 2 - 11 GHz
- FWA services to SMEs and residential users

Interoperable standard

- Defines only one PHY mode: OFDM, FFT 256 points

Main Features

- Using the basic MAC (DLC and CLs) of the IEEE 802.16-2001 standard as base-line
- 12dB higher system gain in uplink, relative to 802.16a OFDM mode, to enable low cost, residential deployment
- Non Line-of-Sight operation
- Advanced antenna systems support

HiperMan: More Details

- **Full QoS support** (scheduled MAC)
- Almost double **protocol efficiency** compared to 802.11a
- Main focus is on **IP traffic**
- Enables **both PMP and Mesh network** architectures
- Supports **both FDD and TDD** frequency allocations
- **Close cooperation with IEEE 802.16**
  - HiperMan and the OFDM FFT256 subset of IEEE 802.16d-2004 standard will interoperate
- **Future enhancements**:
  - License-exempt bands (5.8GHz, etc.)
  - SMNP Management

ETSI BRAN Testing (1 of 4)
Overview

Test specifications are normative part of the standard!

- **Controlled in the open forum in the same way as the base specs**
- **Actual testing and certification is left to industry and their associations**

ETSI Experience

The working methods and approaches have given very good results in terms of interoperability for important technologies (GSM, DECT, similar approach in Bluetooth). 3G is using the same approach and considers the test specifications "very good value for money".

Organization

- **Main work (base specs) done on voluntary basis by ETSI members**
- **Urgent work is progressed through STFs (Specialist Task Force)**
  - STF brings together experts from ETSI members, working together at ETSI premises for limited periods
  - STF funded by ETSI or eEurope
  - STF operates under the guidance of ETSI BRAN
  - Support by ETSI PTCC (Protocol and Testing Competence Center)

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ETSI BRAN Testing (2 of 4)
Comparison of Approaches

Interoperability testing = Two implementations trying to interwork

- Can test only normal behaviour
- Can test exceptional behaviour only by chance

Golden unit testing = An implementation that is somehow representing a standard trying to interwork with an implementation under test

Conformance testing = A test tool evaluating an implementation under test

- Can test both normal and exceptional behaviour
- Can repeat the specific test any time and any number of times (following corrections for example)

As shown on one IEEE802.16 example: The ratio of normal versus total behaviour could be 6/46

ETSI has achieved good results using a combination of conformance testing followed by some level of interoperability testing

ETSI BRAN Testing (3 of 4)
Standards

Basic protocol standard development

- Abstract Syntax Notation (ASN.1) message structure specification, ITU-T X.680
- Packed encoding rules (PER) for transfer encoding, ITU-T X.691
- Message Sequence Charts (MSC) for message flow description, ITU-T Z.120,
- Specification and Description Language (SDL) specification, ITU-T Z.100
  - SDL models used to precisely define the protocol behaviour.
  - Simulations and validations to early remove ambiguities and erroneous protocol behaviour.

Protocol test specifications (ITU-T X.291...296, ISO/IEC 9646)

- **PICS** Protocol Implementation Conformance Statement
- **TSS & TP** Test Suite Structure and Test Purposes
- **ATS** Abstract Test Suite (TTCN)
  - Significant effort was spent (30 man month of funded expert work plus voluntary contribution by member companies and ETSI PTCC work)

Radio test specifications

- **RCT** Radio Conformance Test
- **EN** **Harmonized Standard (European Norm)**, covering the essential requirements of article 3.2 of the EC R&TTE Directives

ETSI BRAN Testing (4 of 4)
STF Funding (in kEUR)

Year	HiperLAN2	HiperAccess	HiperMAN	Total
1999/2000	**160** (STF 150)			**160**
2000/2001	**160** (STF 150b)			**160**
2001/2002	**80** (STF 191)	**245** (STF 192)		**325**
2003/2004	**112** (STF243)	**160** (STF 244)	**156** (STF252)	**428**
2004	**78** (STF 257)	**39**	**98**	**215**
Total	**590**	**444**	**254**	**1288**

~1.5 million USD funding for BRAN test specificatons

Remarks

- Funding by ETSI and eEurope
- HiperLAN2 testing will be completed in 2004.
- HiperAccess testing will continue in 2005.
- HiperMAN testing is very likely to require more funding in 2005 to complete validation

Conclusions for HiperAccess (and HiperMAN)

Requirement		HiperAccess solution
Interoperability	→	Few well-controlled options, ASN.1-based message encoding, detailed test specifications.
Spectral efficiency	→	Adaptive modulation & coding, adaptive power control.
High QoS	→	Centralized radio link control, centralized scheduling, robust messaging.
Low cost design	→	Large network-independent part option for TDD, support of H-FDD.
Future proof	→	Several further options, „hooks“ for future evolution, phased roll-out: 1st ATM, 2nd IP

BRAN - Plans for New Activities and Next Steps

- **HiperLink @ 17 GHz, WLAN @ 60 GHz**
- **Harmonized Standards (HL, HA, HM)**
- **Extensions for HM**
  (mobility, MIB specification, new or additional PHY modes, provisions for self-installation, etc.)
- **Harmonization between HA and WirelessMAN-SC**
- **Service for rural areas and low densities**
- **Alternative and improved testing methods**
  (e.g. testing of protocol prototypes over IP rather than over radio interface)
- **Ongoing fine-tuning of all BRAN standards**

For more information ...

BROADBAND
RADIO
ACCESS
NETWORKS

- **http://portal.etsi.org/bran**
  (ETSI portal)

- **http://www.etsi.org/ptcc**
  (ETSI PTCC and testing issues)

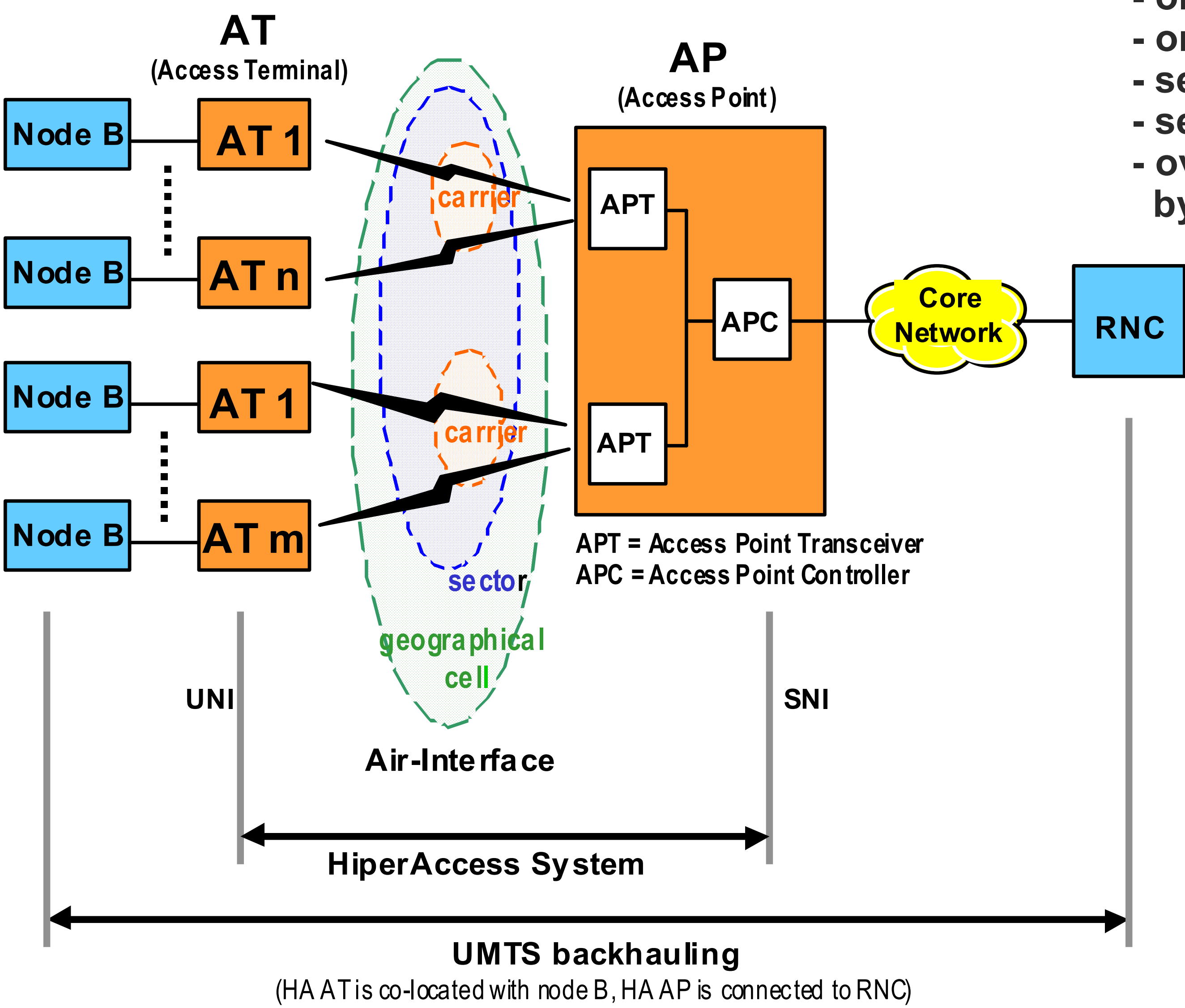
- **bernd.friedrichs@marconi.com**
  (BRAN Chairman)

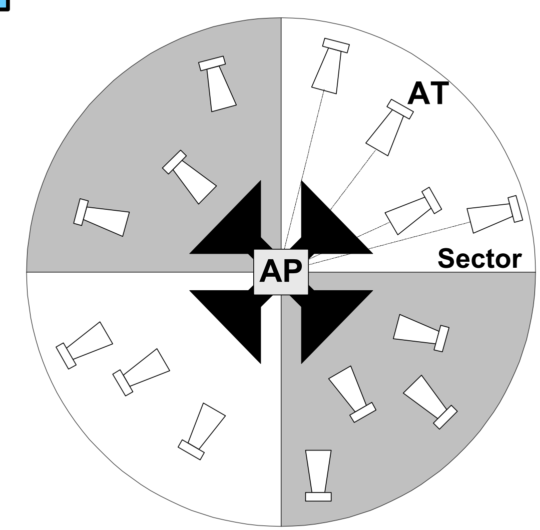
Technical Annex

- **Technical Details HiperAccess**
- **Link Budget**
- **Multiplex Gain**

HiperAccess: Network Topology Model

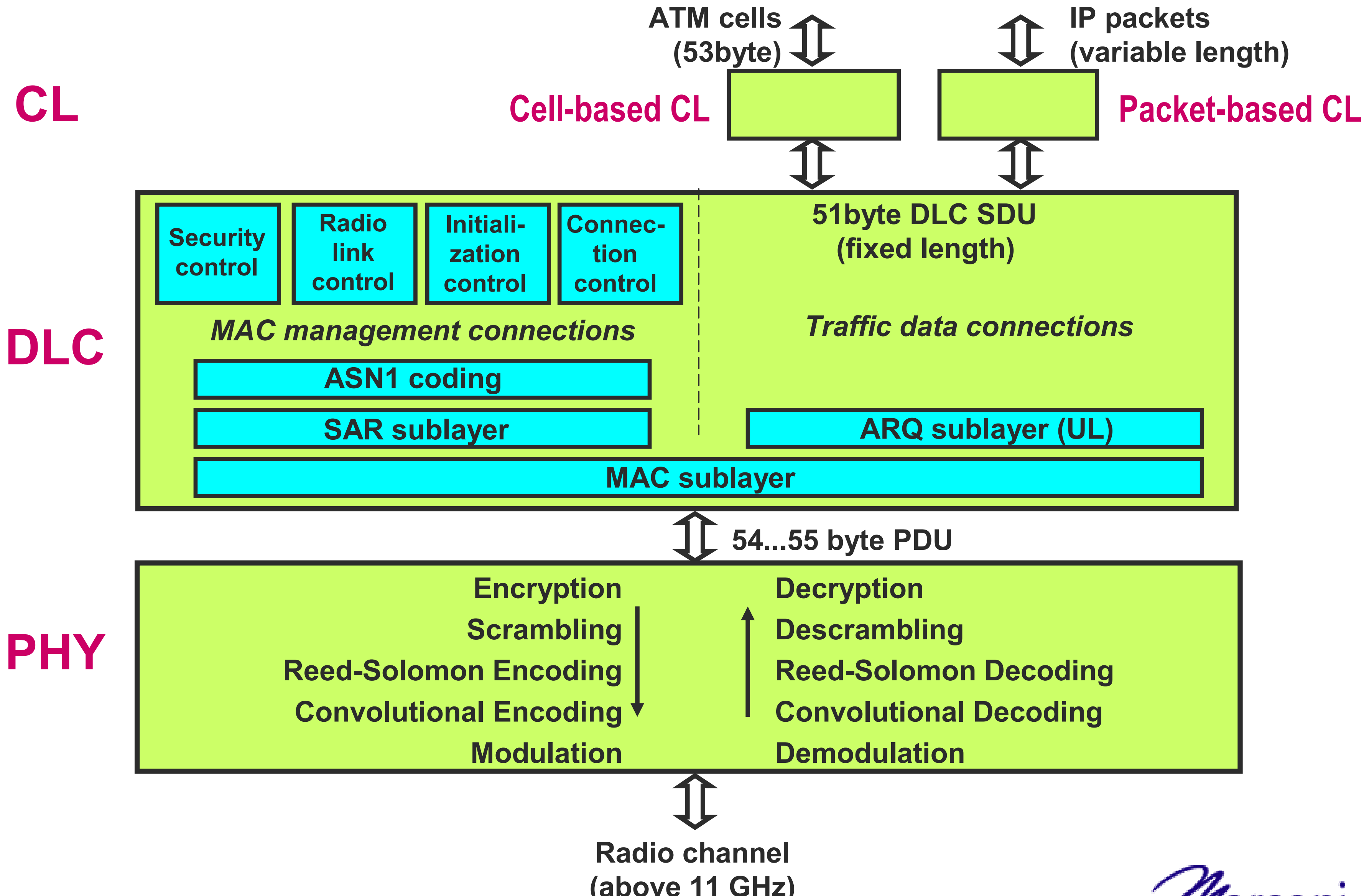
- one APT per carrier
- one APC per cell
- several sectors per cell
- several carriers per sector
- overlapping cells (separated by frequency or polarization)



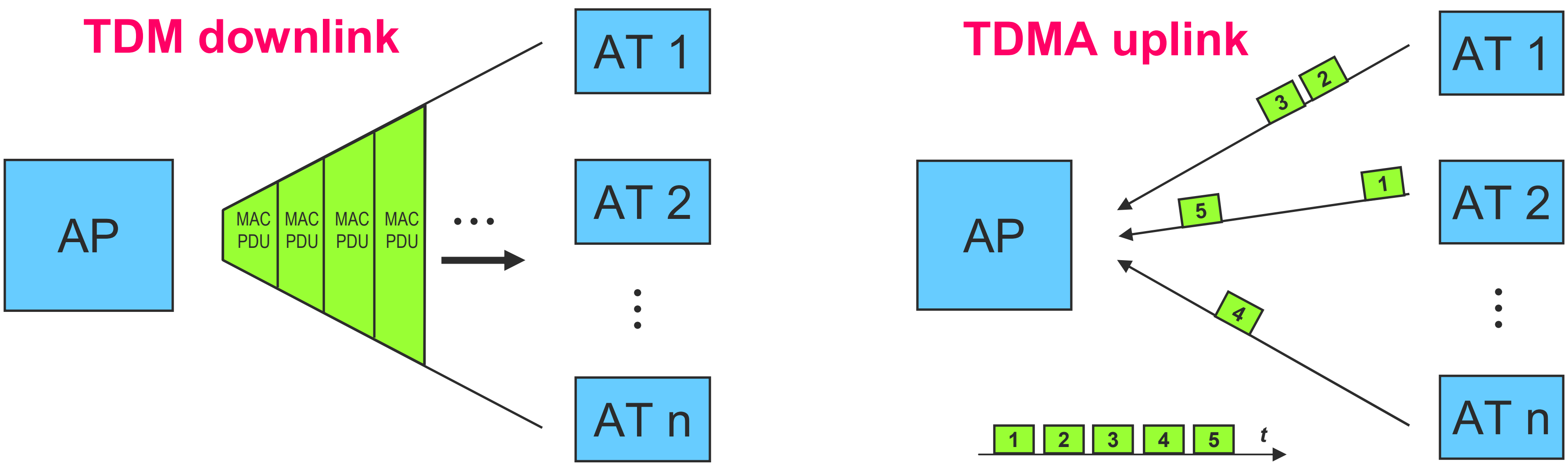


Cell with four sectors

HiperAccess: Detailed Layer Structure



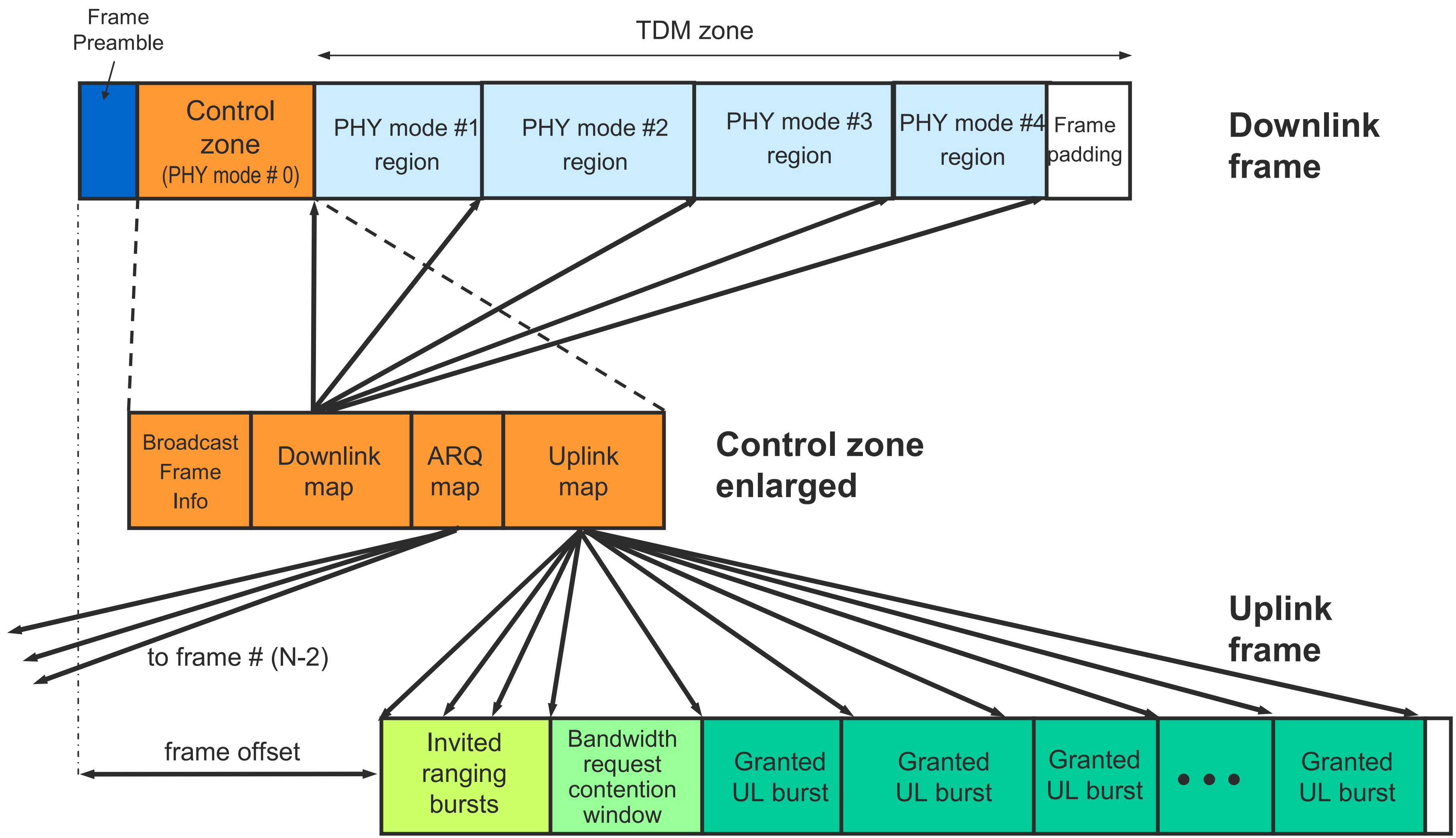
HiperAccess: TDM in Downlink, TDMA in Uplink



Further important properties of downlink and uplink

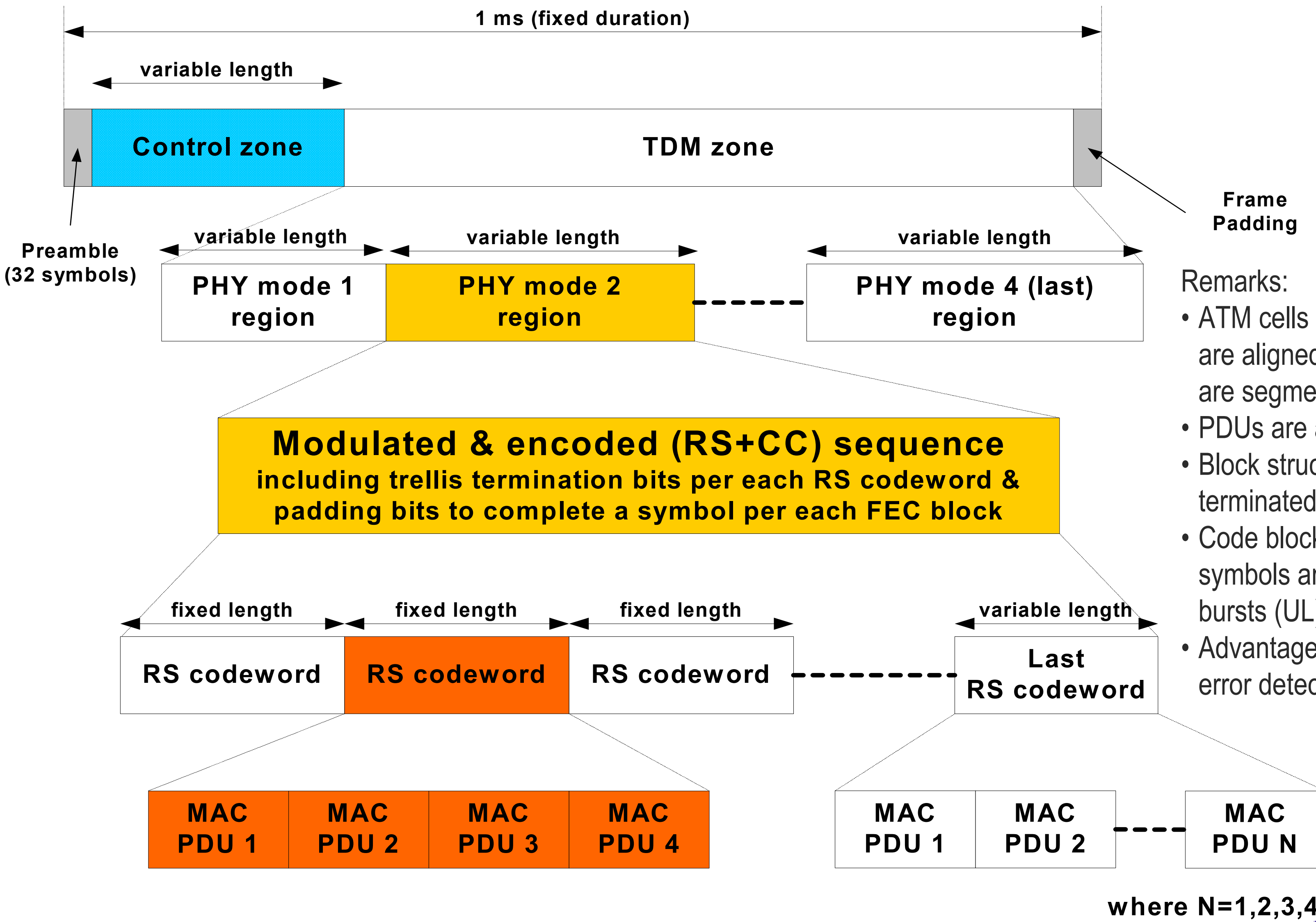
	Downlink	Uplink
Link budget & rain fading & multipath propagation	approx. identical	
Co-channel interference	time-invariant from other APs	time-variant from other ATs
Transmit power (same bandwidth)	constant for all ATs	individual per AT (distance, modulation, fading) for constant RX power

HiperAccess: Frame Structure



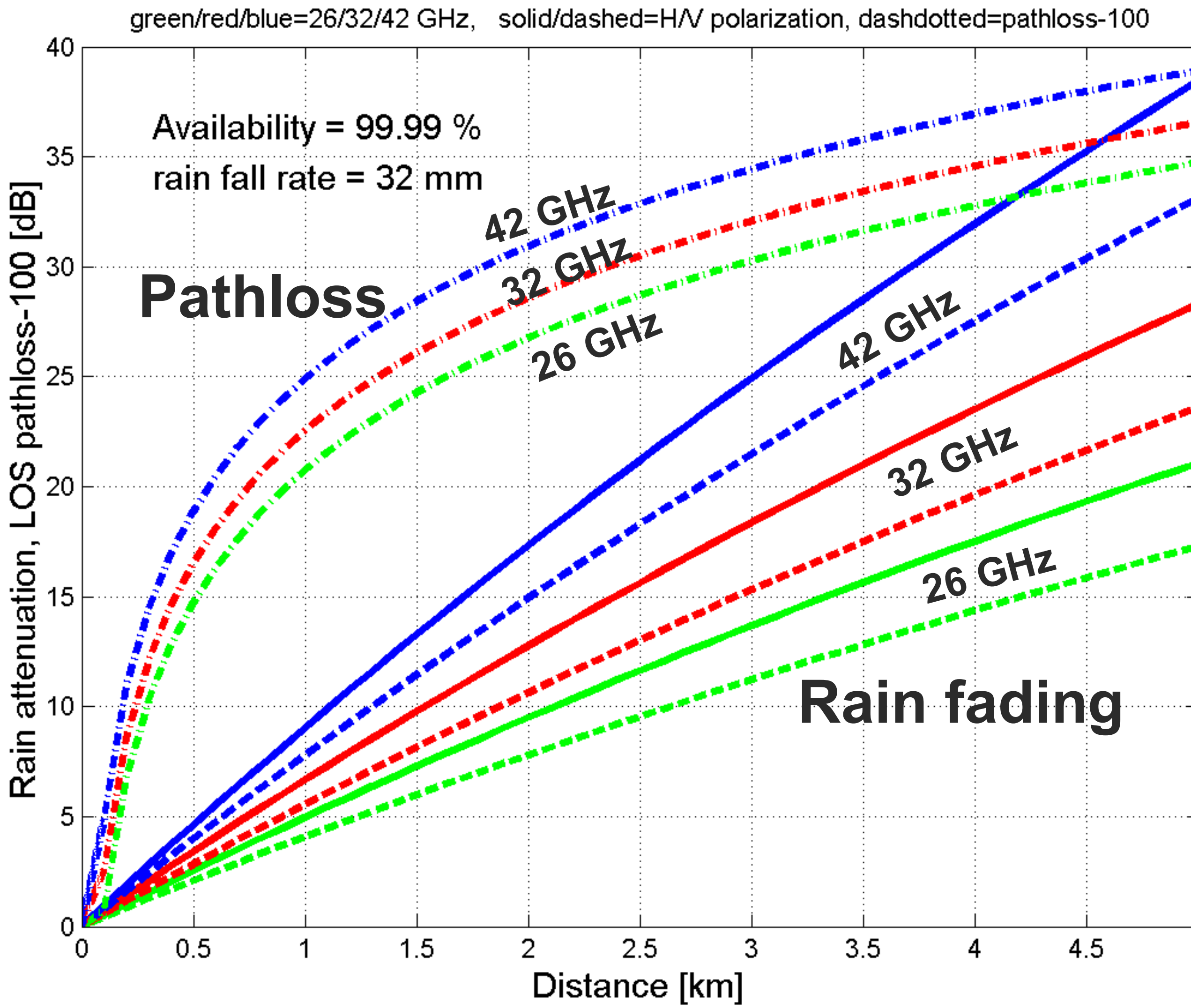
Order of ranging burst and contention window is just an example

HiperAccess: Concatenated Coding

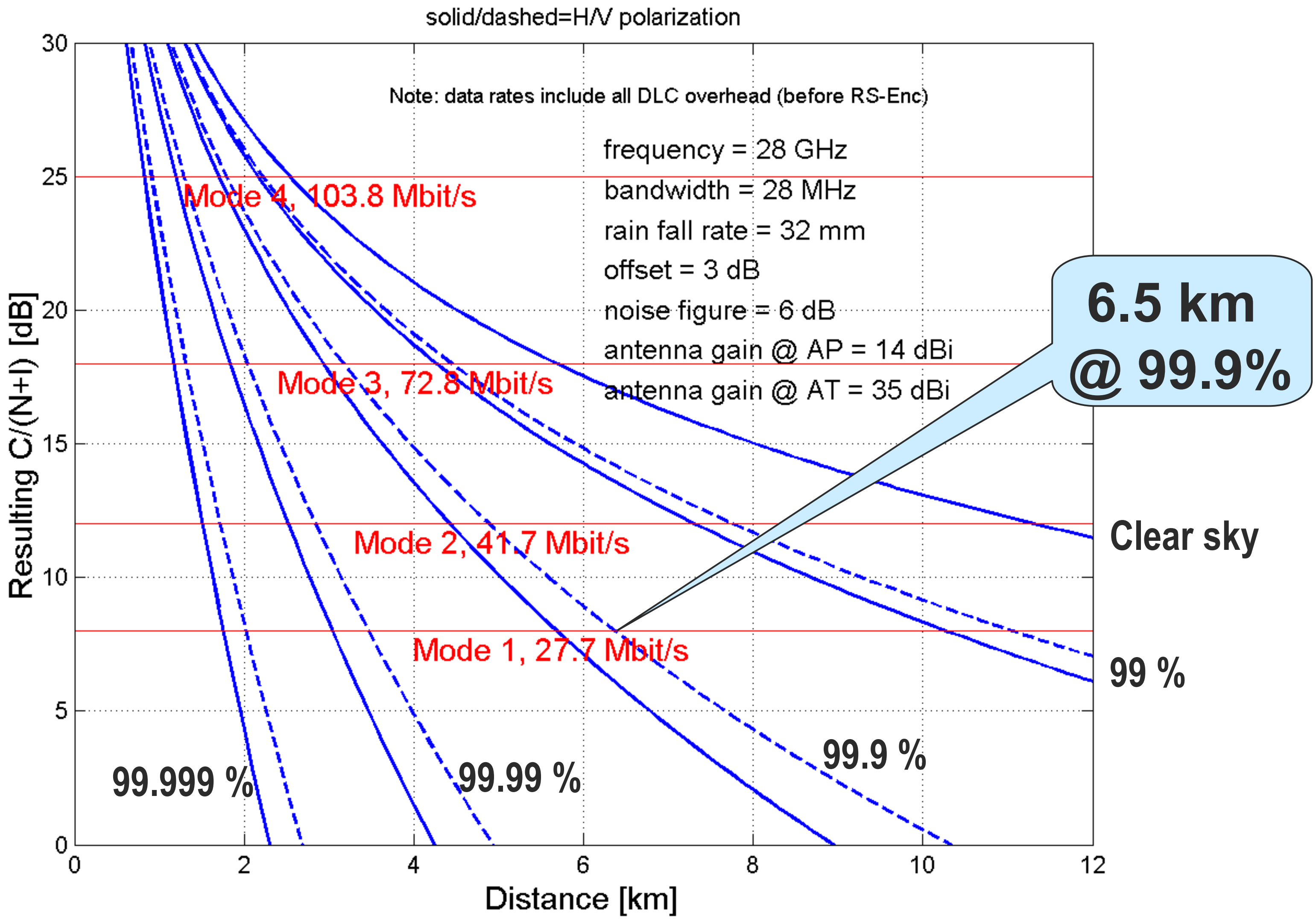


Remarks:
- ATM cells and DLC messages are aligned to PDUs, IP packets are segmented to PDUs
- PDUs are aligned to RS blocks
- Block structure preserved by terminated convolutional coding
- Code blocks are aligned to symbols and regions (DL) and bursts (UL)
- Advantages: error detection and ARQ

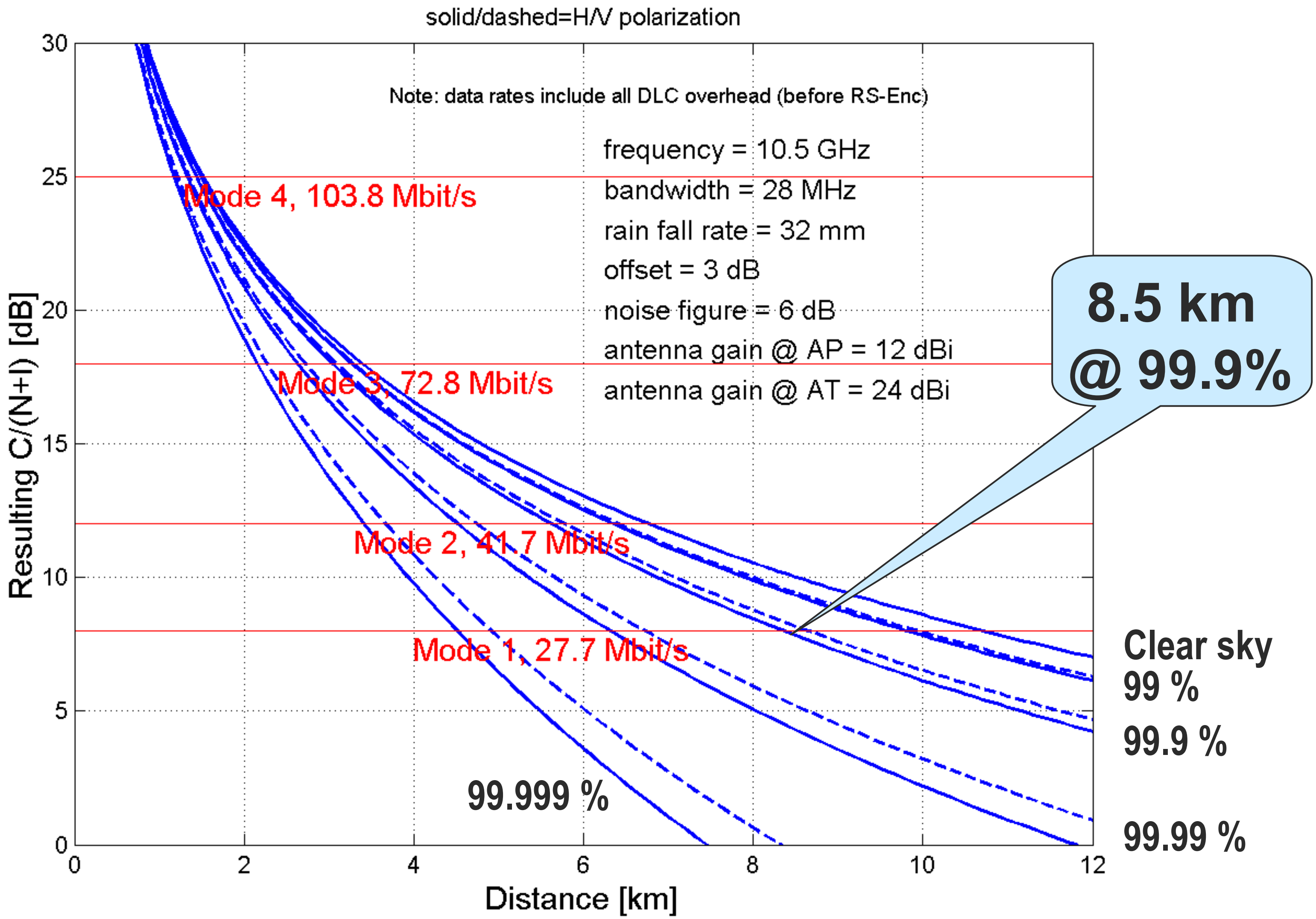
Link Budget: Free-Space Loss and Rain Fading



Range and Throughput for PMP @ 28 GHz for various availabilities



Range and Throughput for PMP @ 10.5 GHz for various availabilities



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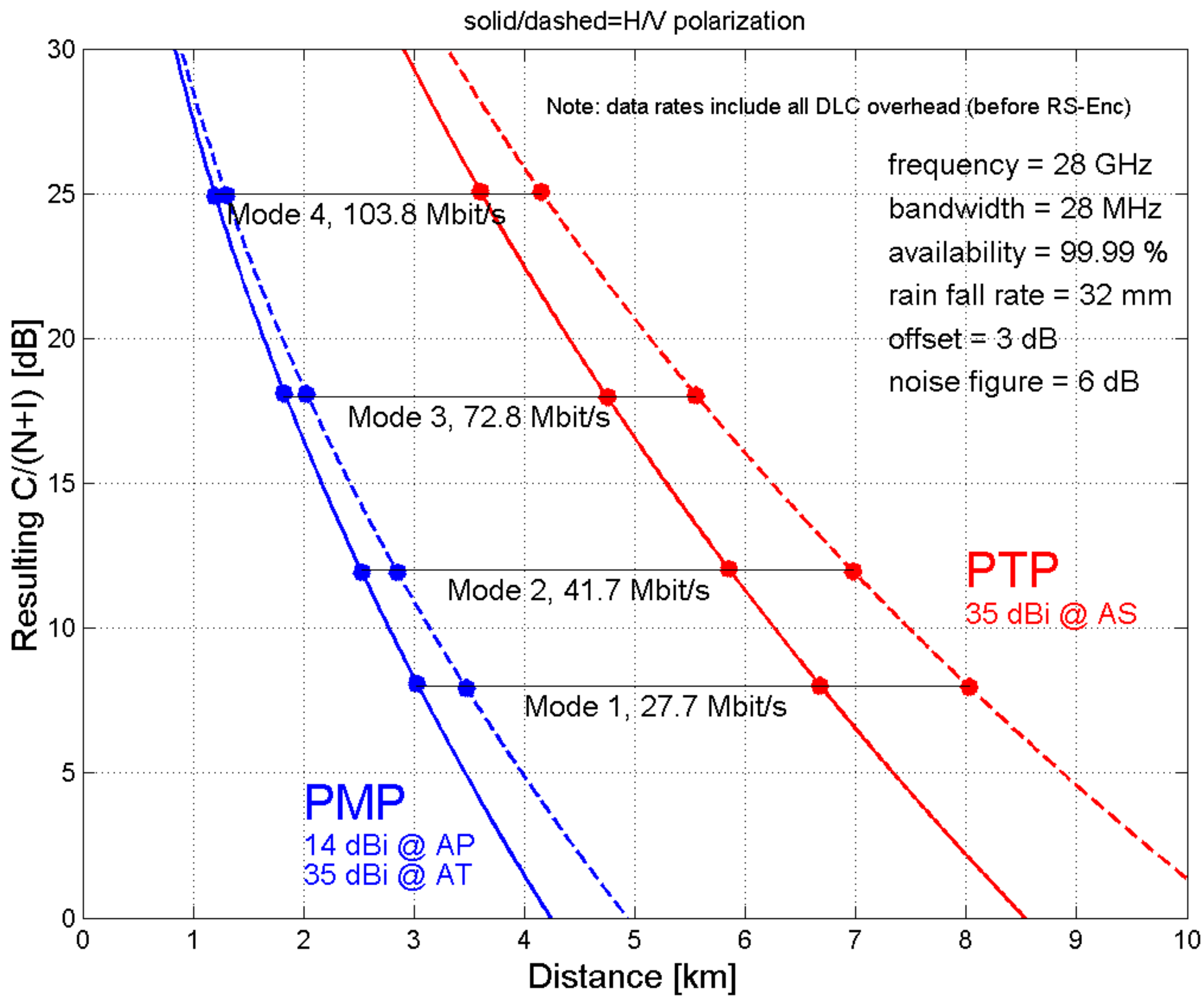
Range and Throughput: PMP versus PTP
@ 28 GHz, 15 dBm, 99.99%, rain zone H



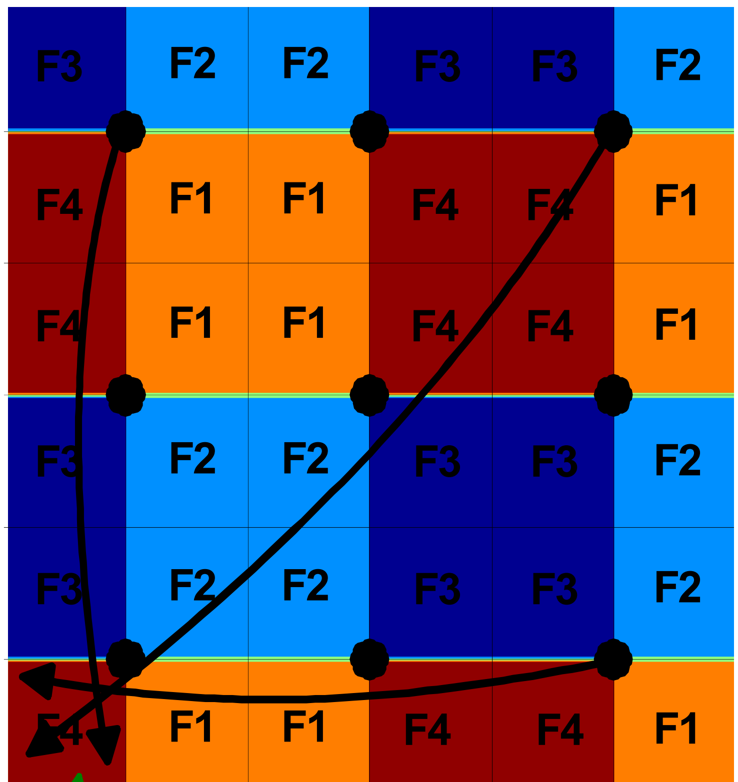
HiperAccess: Maximum Range

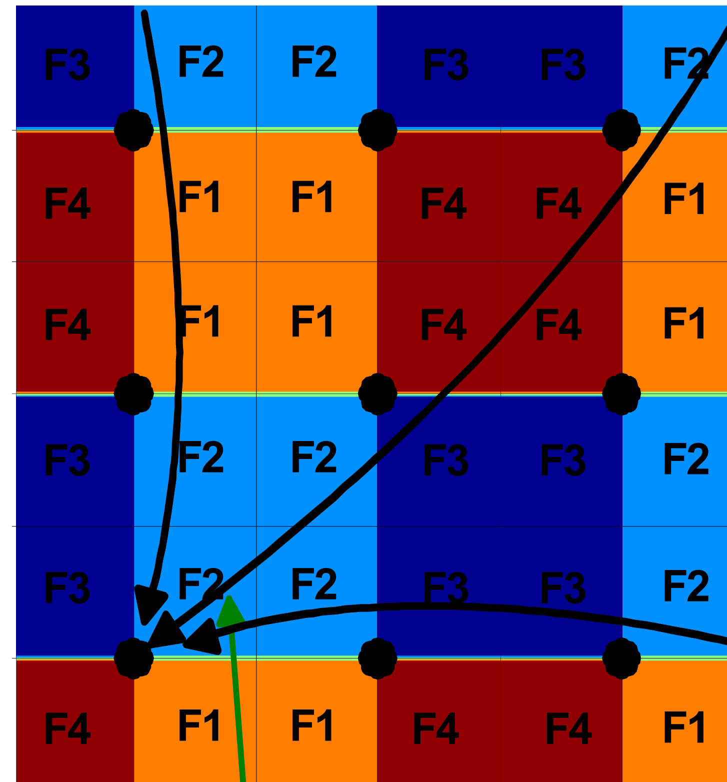
- High frequencies: the range depends on rain zone and requested availability (e.g. for availability=99.9%)
  range = 6.5 km @ 28 GHz
  range = 8.5 km @ 10.5 GHz
  Higher ranges are possible for clear sky (the higher the frequency, the larger the effect)

- Range extensions are possible
  for lower frequencies
  for narrow carriers (e.g. 7 GHz instead of 28 GHz)

- For very narrow-beam base station antennas (i.e. PMP approaches PTP), the range extends as follows
  range = 3.5 km for PMP (4 sectors)
  range = 8.0 km for PTP
  (assuming 28 GHz, availability=99.99%)

Interference in Downlink and Uplink





DL worst sector

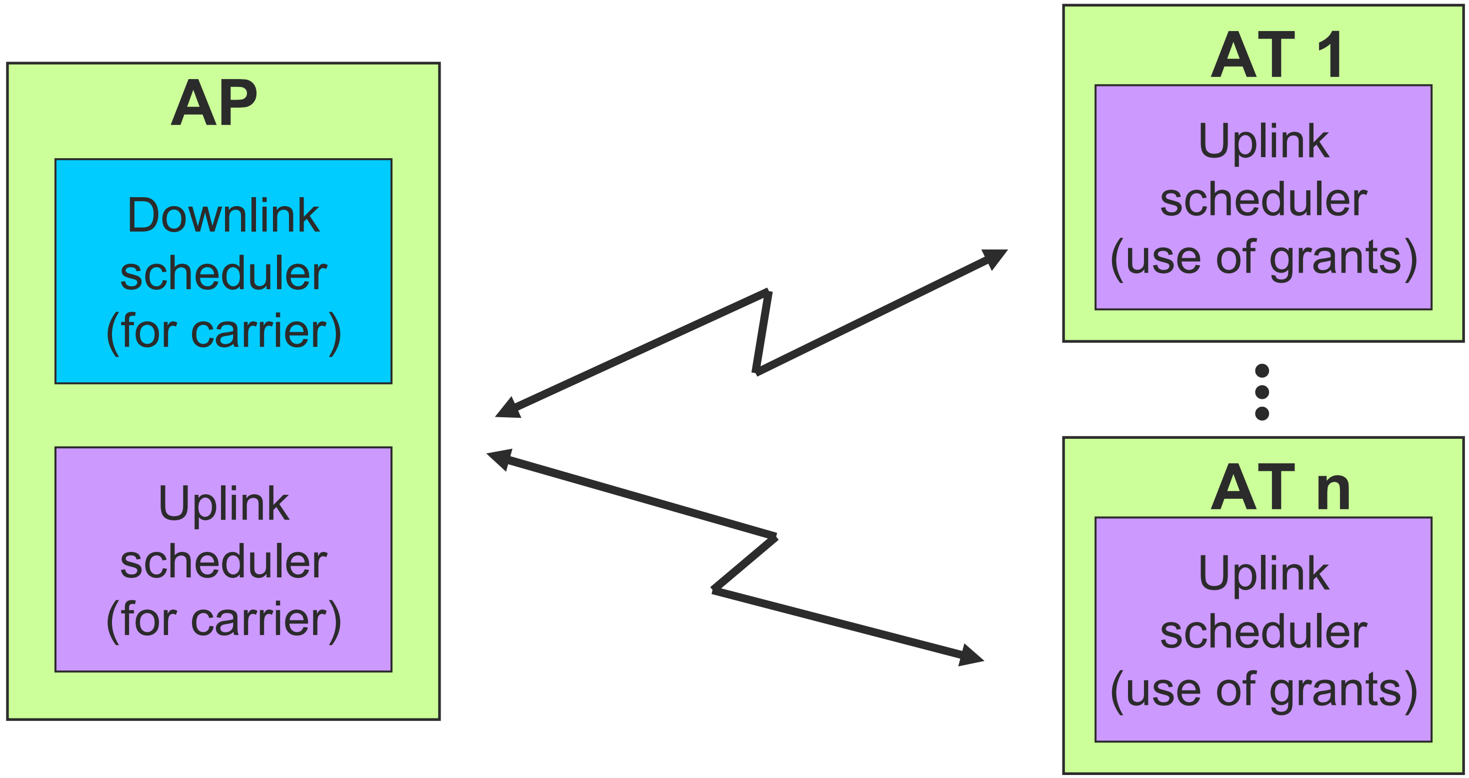
$(C/I)_{min} = 20*\log(5) = 14.0$ dB

UL worst sector

Interference degradation typically depends on direction

- **a sector may have poor properties for DL but good properties for UL**
- **interference is time-invariant for DL and time-variant for UL**

HiperAccess: Bandwidth Allocation



Downlink allocation

via DL map
(no action from AT)

Uplink allocation

Requests per connection aggregate (various mechanisms)

Grants per terminal via UL map

HiperAccess: Security (Privacy, Authentication)

Phased approach

- Phase 1: Fixed keys (relax management requirements)
- Phase 2: Authentication and frequent key exchanges for high-level security
- Phase 3: Privacy for multicast

Algorithms

- Block ciphers: DES, 3DES, AES, CBC mode
- Hash functions: SHA-1
- Certificates: X.509
- Asymmetric keys: RSA (PKCS)

Statistical Multiplex Gain (1 of 2)

A PMP system performs like a virtual multiplexer:

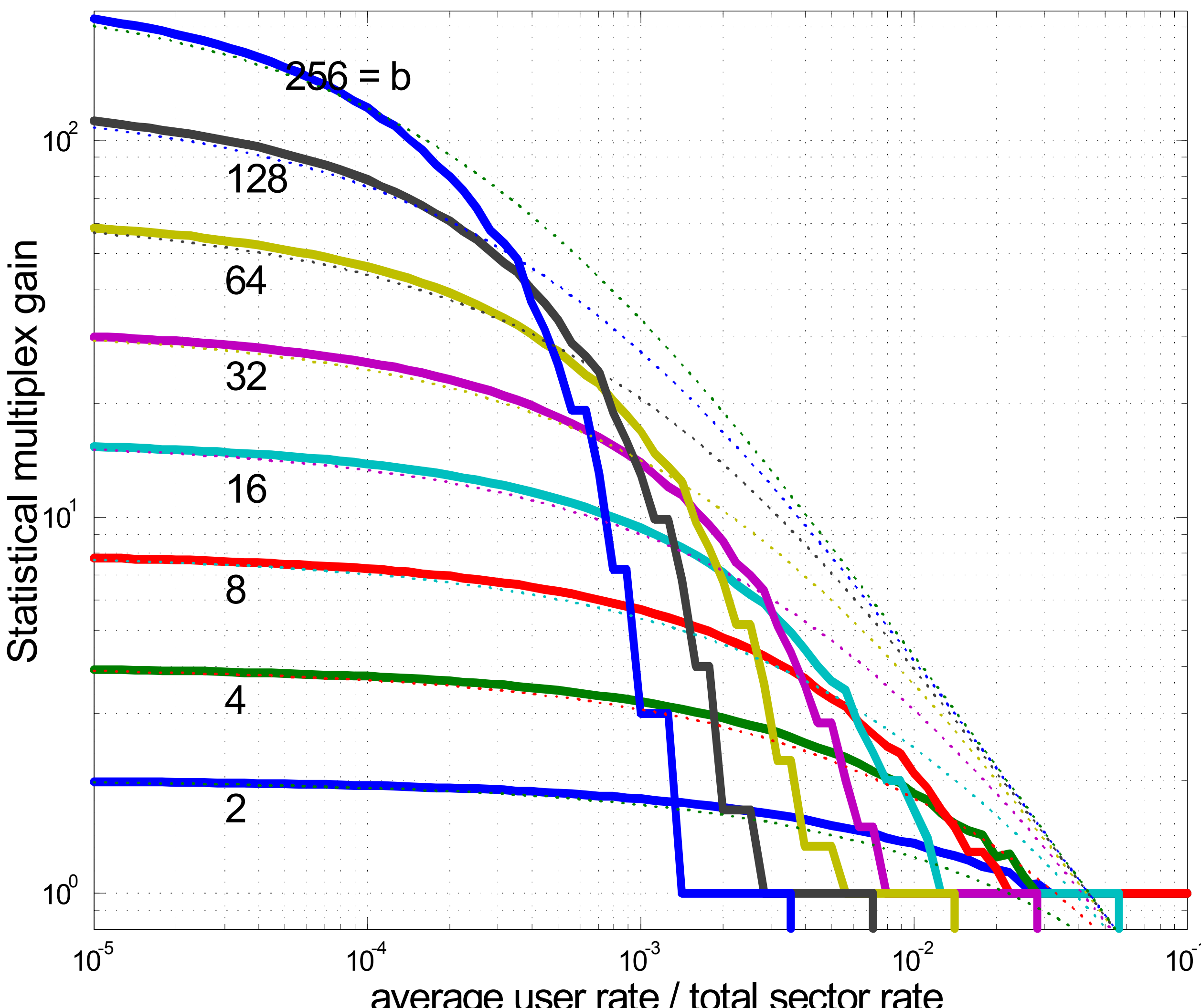
Statistical multiplexing with a small CLR (cell loss rate) allows higher total data rates than fixed allocation guaranteeing peak data rates. Formally,

$$G = \frac{\text{throughput with statistical multiplex}}{\text{throughput with static collision-free multiplex}}$$

The multiplex gain of a PMP system increases with

- **larger bandwidth**
- **larger number of terminals**
- **higher burstiness (e.g., VBR, UBR)**
- **tighter delay constraints (e.g., CBR, rt-VBR)**
- **smaller CLR**

Statistical Multiplex Gain (2 of 2)



Conditions:

CellLossRate = 10^{-6}
DelayTolerance = 0

Legend:
b = burstiness