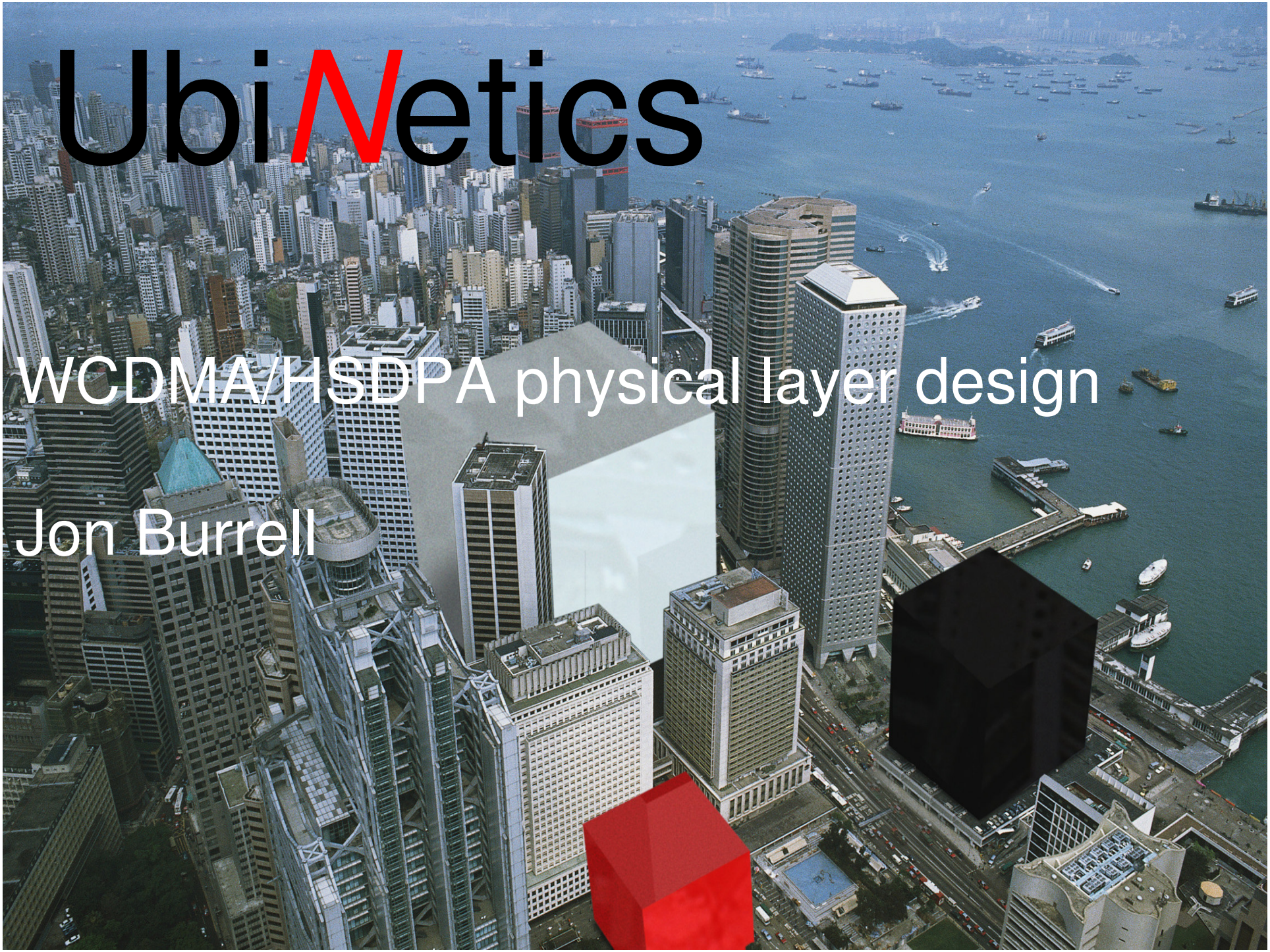
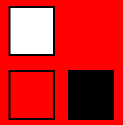

UbiNetics
WCDMA/HSDPA physical layer design
Jon Burrell

Content

- Importance of WCDMA
- Crash course in WCDMA
- WCDMA implementation
- Why HSDPA
- Crash course in HSDPA
- HSDPA implementation

Terminal physical layer only, downlink bias and selective!



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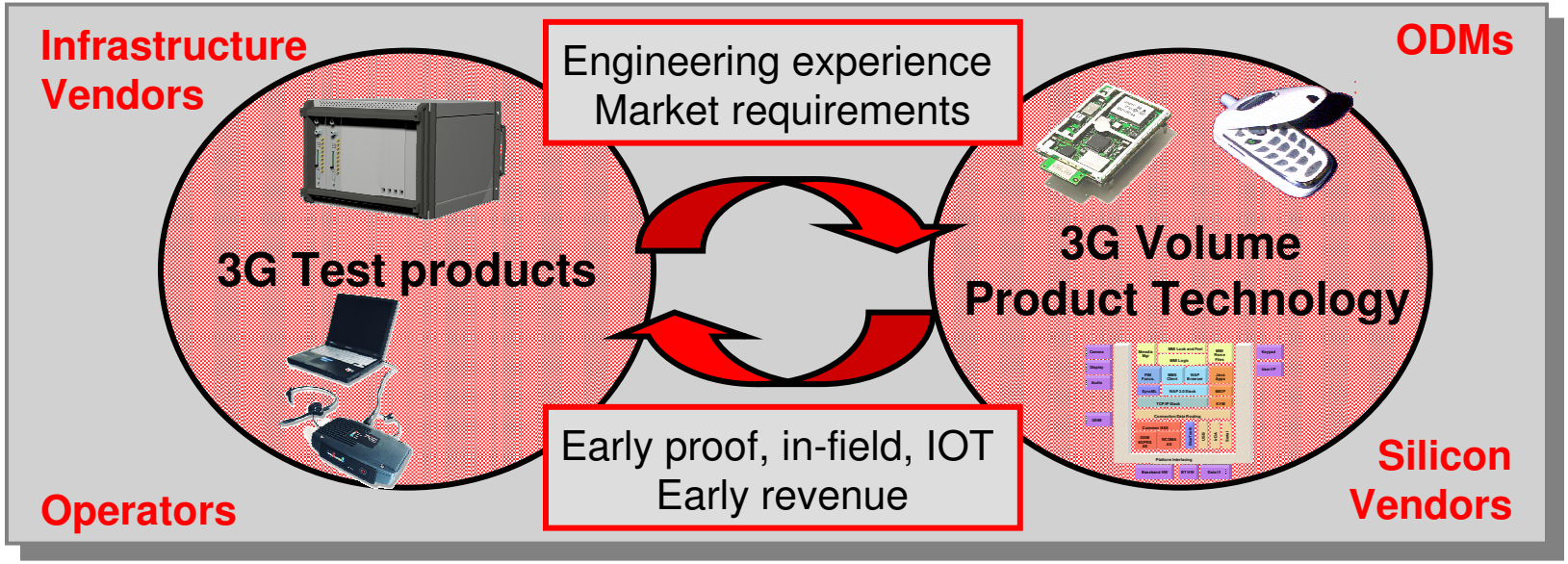
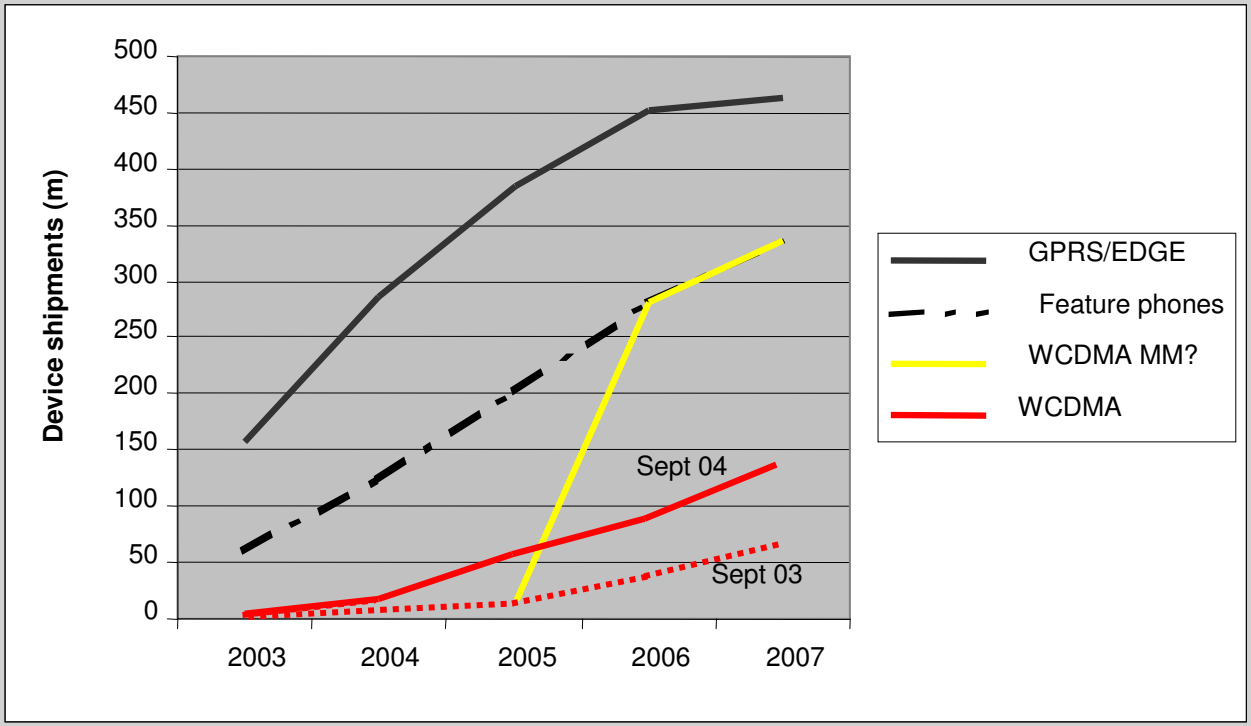
UbiNetics outline

3G (HSDPA/WCDMA/EDGE/GPRS) handset technology



- Cambridge UK based, founded January 1999 and now 400 staff
- R&D centres in Bangalore, Cambridge, Swindon and Shenzhen
- Sales and customer support centres Hong Kong, Tokyo

WCDMA Importance



Source: Ovum / DB

Underestimated prediction for WCDMA/EGPRS technology?

WCDMA (multimode) phone technology will dominate

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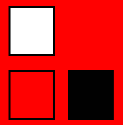
What is WCDMA?

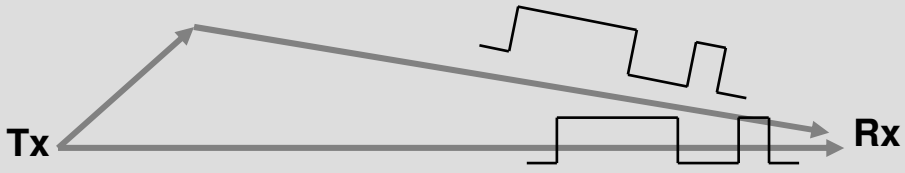
Layer 1 perspective

- Wideband 5 MHz. (For each of DL and UL)
- Single frequency all users and all cells
- DS spread spectrum
- User and cell separation by spreading code
- Fast power control
- Soft handover
- QPSK
- Turbo coding
- Multiple transport channel combinations
- 384 kbps

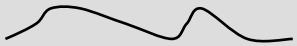


Essentials 1: Diversity gain

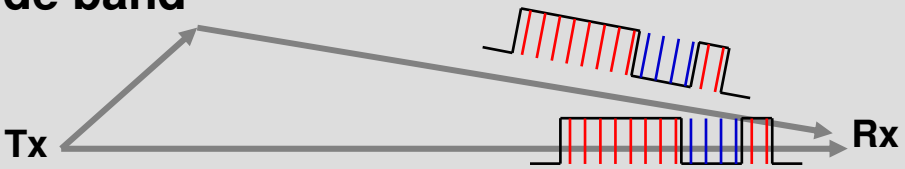
Narrow band



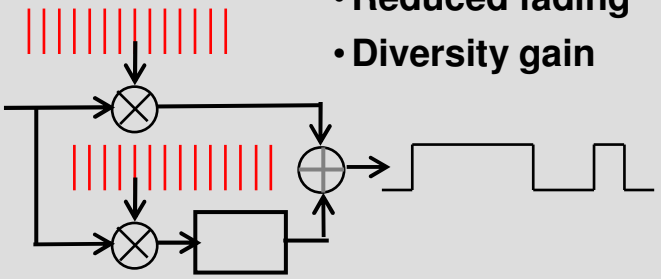
- Cancellation, deep fading
- Inter-symbol interference



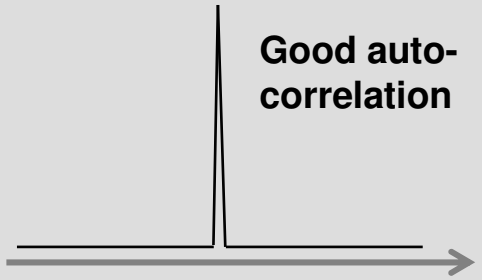
Wide band



- Reduced fading
- Diversity gain



- Spread signal with pseudo random sequence at high “chip” rate
- Spreading code with good autocorrelation function
- Receive by synchronous correlation to resolve multipaths and coherently combine - Rake
- Autocorrelation function fails at < 1chip
  - Transmit Diversity to the rescue



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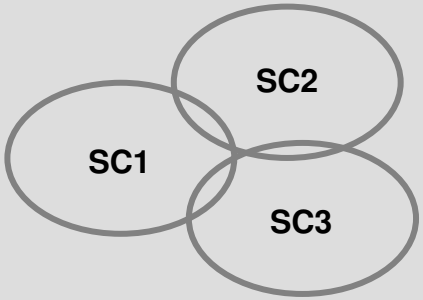
Essentials 2: Spreading Codes

Spreading is a combination (multiplication) of two codes:

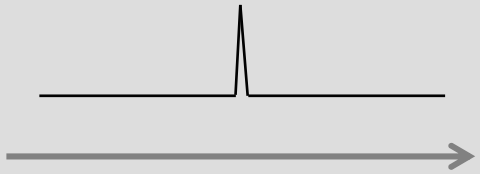
- Orthogonal Variable Spreading Factor (OVSF)
  - Separates users in a cell (in DL)
  - Variable length: defines data rate
  - Perfect cross-correllation. If aligned!
  - Very poor auto-correllation

OVSF1: 00001111
OVSF2: 00110011

- Scrambling codes (SC)
  - 10ms long PN sequence
  - Very good correlation properties
  - Separates and identifies cells in DL
  - (Separate users in the UL)



- But the codes are not perfect
  - Intra-cell interference through loss of OVSF orthogonality in multipath
  - Inter-cell interference from neighbough cell SCs



CDMA systems are interference limited, so....

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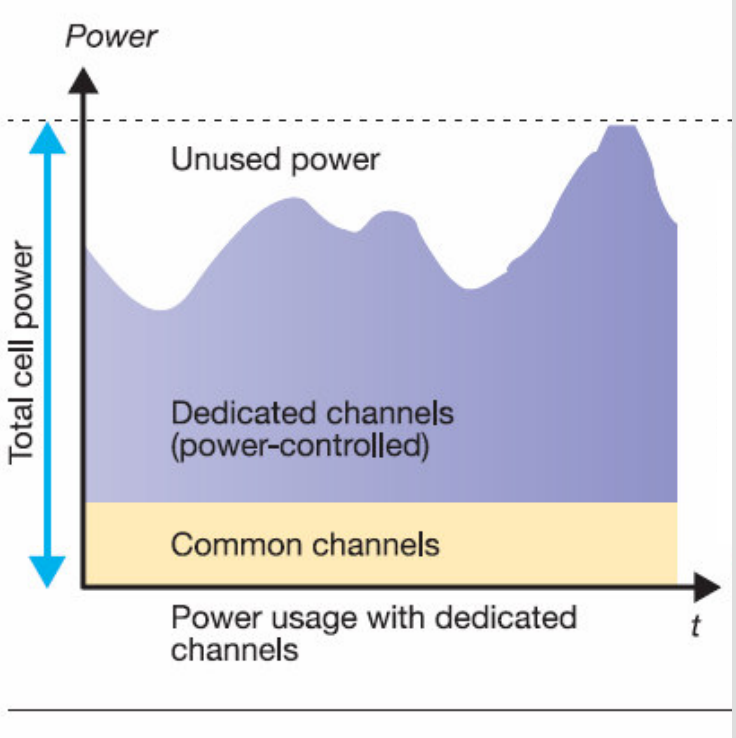
Essentials 3: Power control



- Very important in the UL because of “near far” problem
- Reduces interference in the DL by minimising cell power
- Fast closed loop power control used in both UL and DL
- Received SIR determines TPC feedback
- Fast feedback requirements, ~70us, a considerable challenge for physical layer design

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Essentials 4: 3G vs 2G

WCDMA gains from:

- Better spectral efficiency of CDMA vs TDMA
- QPSK, and turbo coding

Makes *WCDMA ~5x more efficient than GSM*

Table 7. Comparative Costs of Providing Data

	GPRS	WCDMA
Access Revenue/User/Month [1]	**$40.00**	**$40.00**
Cost/Mbyte @ Capacity [2]	$0.415	$0.069
Mbytes/Month/User	268	268
Network Cost/User/Month	**$111.22**	**$18.49**
Sales & Mktng and G&A/User/Month[3]	$16	$16
Earnings Before Interest & Taxes	–$87.22	$5.51
EBIT Margin	***–218%***	***14%***

6x cheaper

[1] Source: Morgan Stanley Dean Witter; The Mobile Internet Report; 10/00; p.52. Estimates affordability of wireless data to be $25–$50 per month

[2] Excludes amortization of spectrum costs.

WCDMA: high speed, flexible data services, low cost

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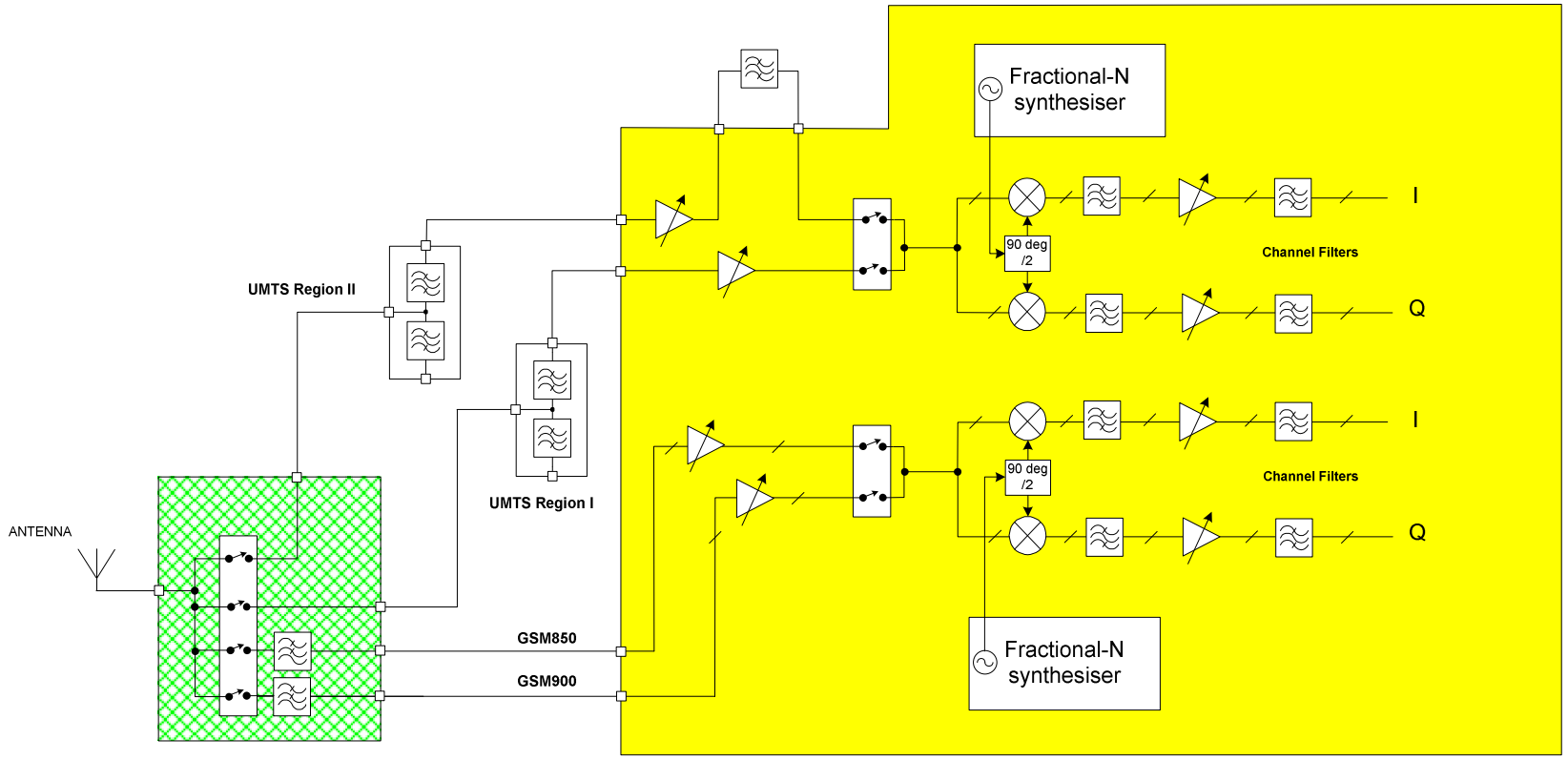
WCDMA RF Design (receiver)



- Direct conversion receiver gives competitve design – low BOM
- But must be careful to minimise DC offset
- Trick is to remove DC component but retain fast settling on gain step
- *UbiNetics has developed an WCDMA RF chip with Renesas*

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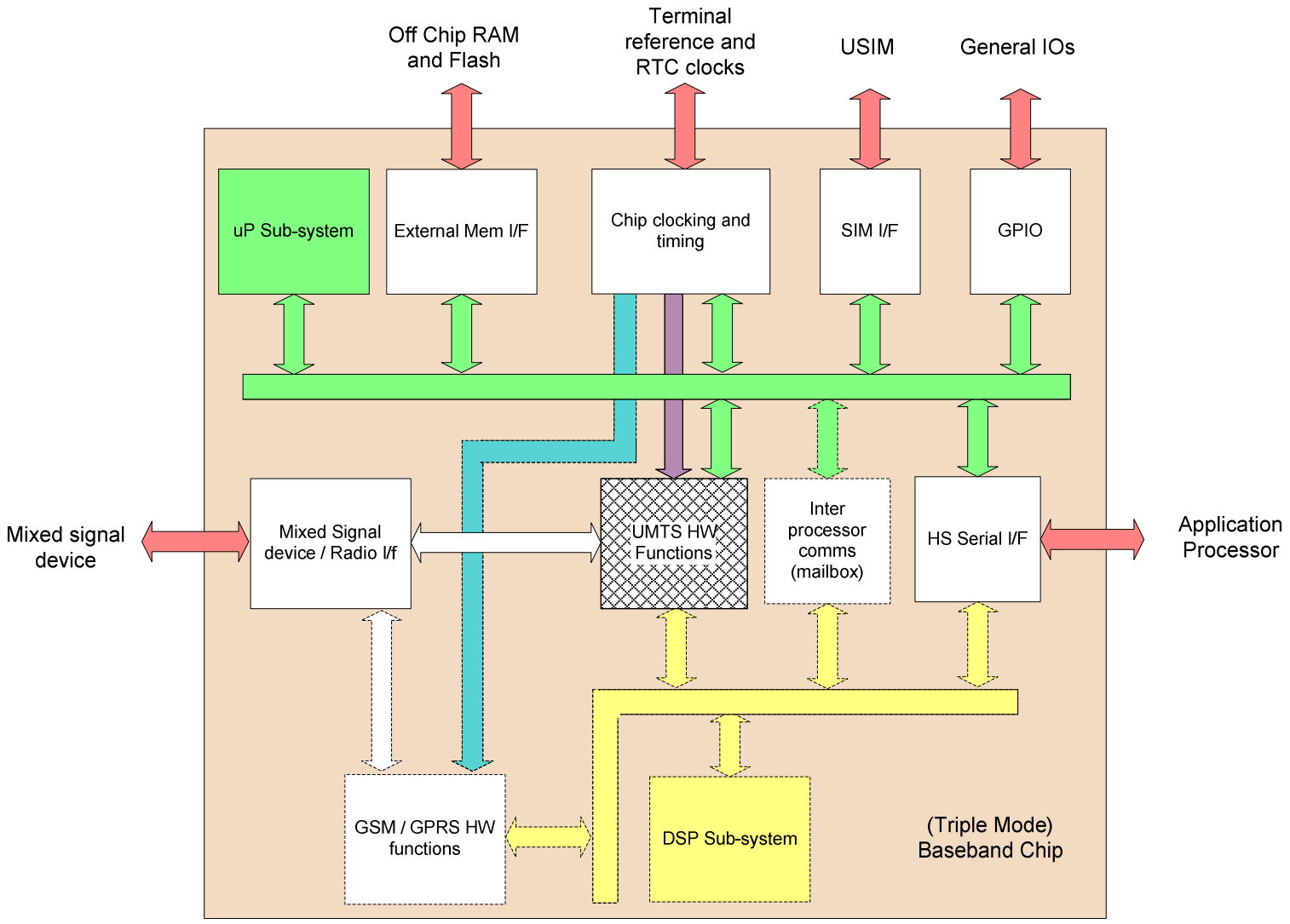
Multimode SoC Block Diagram



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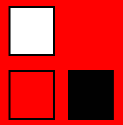
UbiNetics WCDMA SoC design

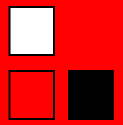
- Release 99, 384kbit/s class UMTS IP core
- Low power hardware centric design
- No DSP required for data centric operation
- ARM 9 class controller required (926 assumed)
- “Bolt-on” HSDPA support
- MM support “designed in”

Working with 2 major semis



WCDMA HW/SW Partitioning

- Functions implemented in hardware
  - Traffic data path (chip and bit rate)
  - Bandwidth intensive processes (e.g. Psync peak sorting)
  - Low latency processes (e.g. power control)
- Remaining functions partitioned by
  - Size and complexity
  - 'Intelligence' residing in software (e.g. AGC loop)
  - Power consumption advantage
  - Bus bandwidth



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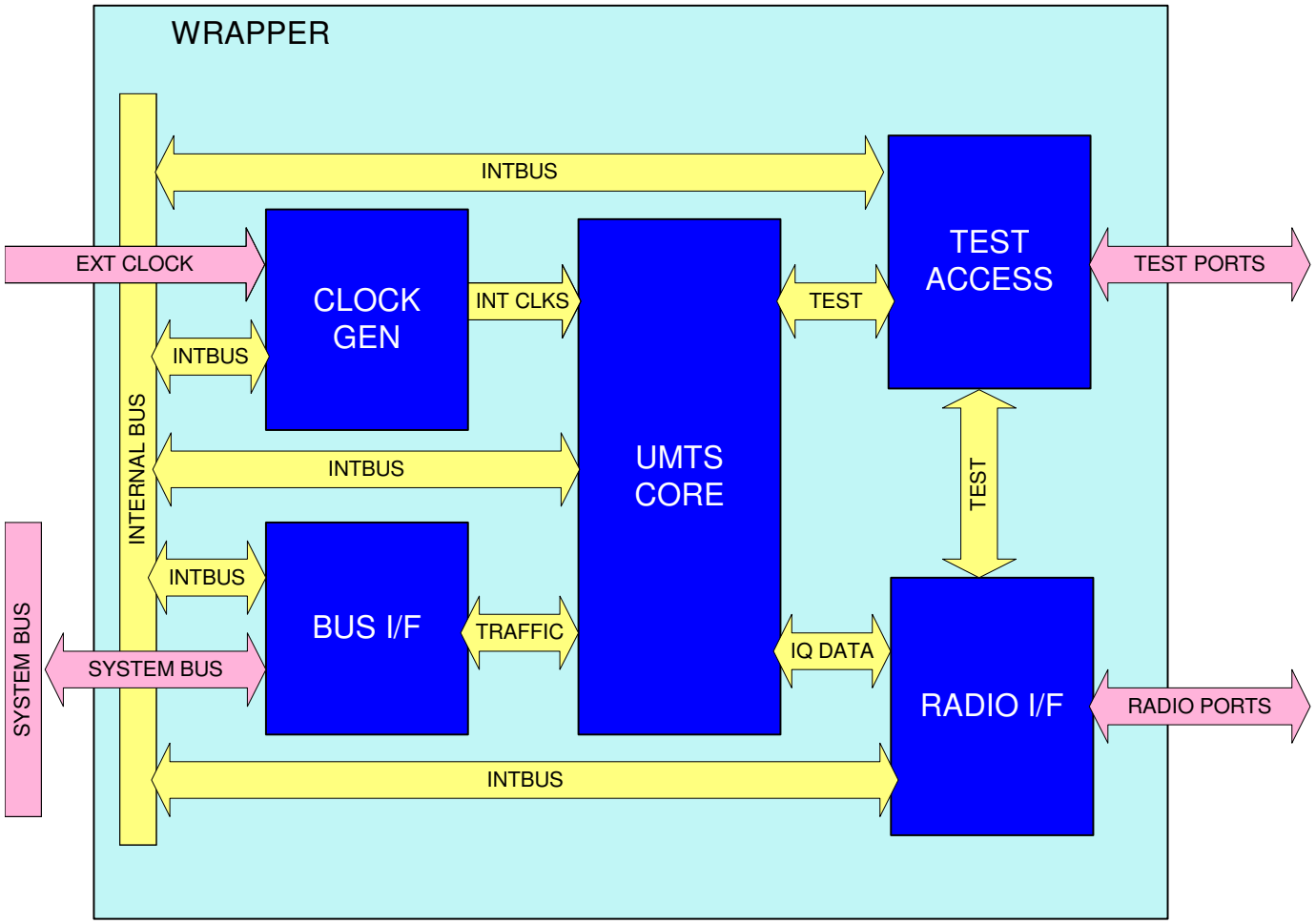
WCDMA H/W block diagram



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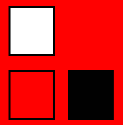
WCDMA rolling-out, however..

- The ‘other’ 3G standard CDMA2000 had a head start
- WCDMA will dominate long term, but
- CDMA2000 has a high rate, ~ 3 Mbps, DL extension 1x EV-DO in operation now
- Sprint and Verizon in US, KDDI in Japan using it
- Customers like high speed
- DoCoMo, Vodafone (Japan) and Cingular/AWE (US), WCDMA operators, are nervous

*Resultant push for **High Speed Downlink Packet Access** enhancement to WCDMA*



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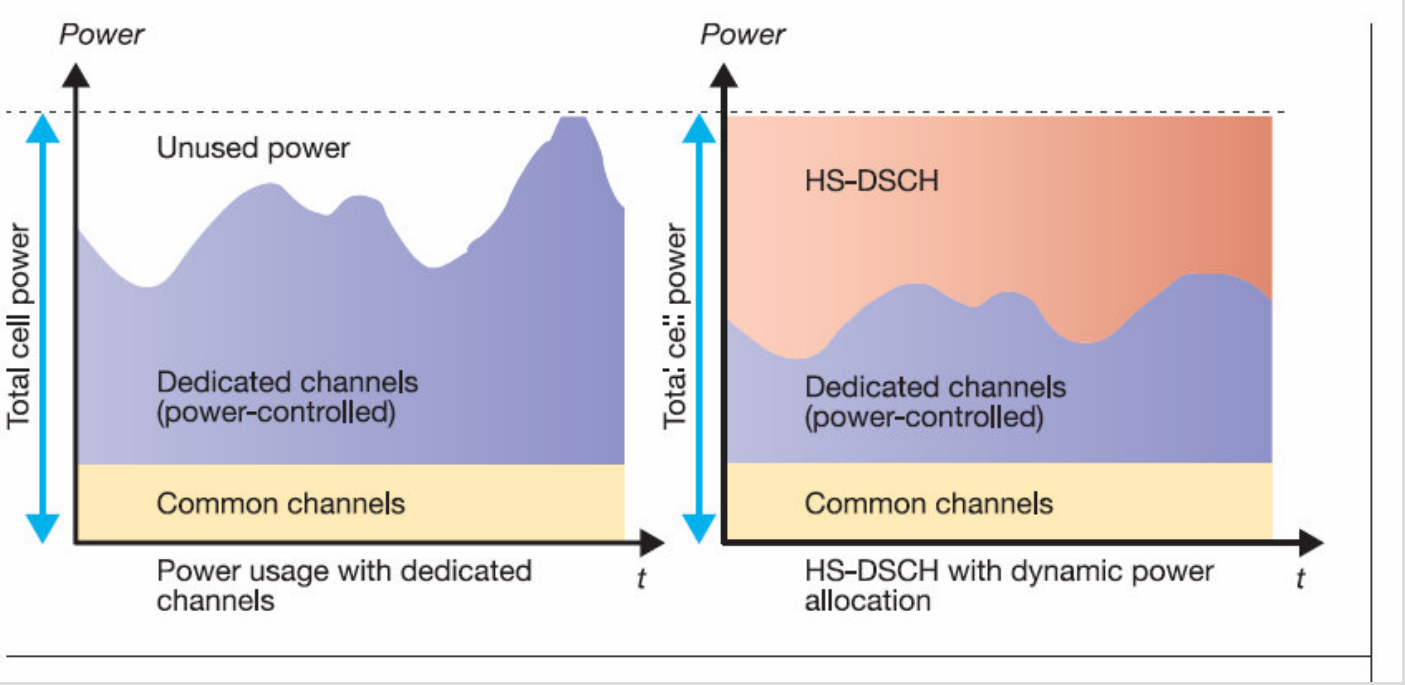
What is HSDPA?

- Increased packet data support in the DL
  - More efficient use of the available bandwidth
  - Increase maximum user throughput for downlink packet data
  - Increase the peak data rates to 14 Mbps
  - Reduce the latency for packet data
  - Minimise the need for additional control signalling
- Compatibility with R99
  - HSDPA is a straightforward enhancement to R99 architecture
  - All R99 techniques can be supported in an HSDPA network
  - R99 and HSDPA mobiles can co-exist on the same frequency
- Scalable UE Complexity
  - 12 categories of terminal capability
- Target urban and indoor environments

Essentials 1: Unused power

“Unused” power capacity allows greater throughput



By:

- User scheduling by Node B
- Adaptive modulation and coding (AMC)
- Hybrid automatic repeat request (HARQ)

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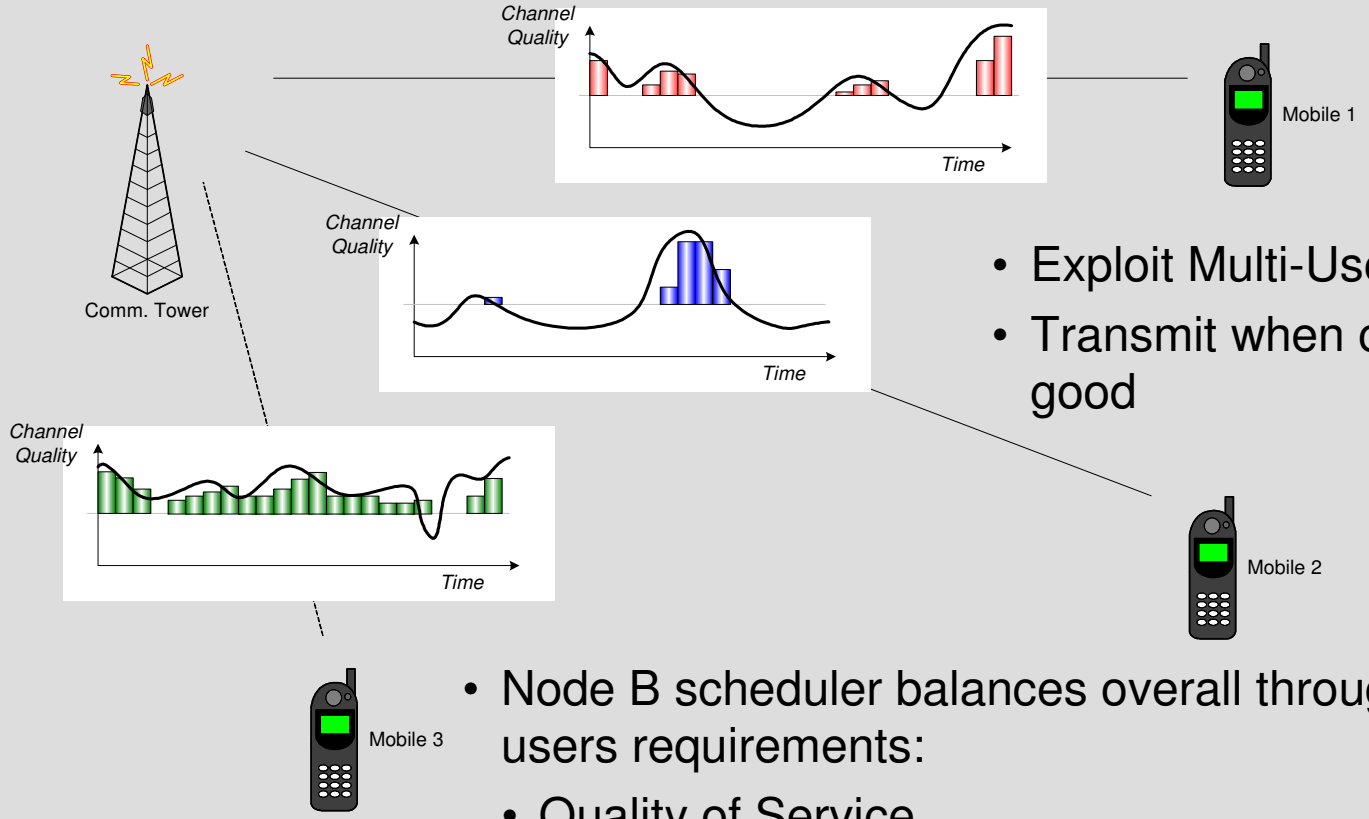
Essentials 2: Scheduling



- Exploit Multi-User Diversity
- Transmit when channel is good
- Node B scheduler balances overall throughput and users requirements:
  - Quality of Service
    (Conversational, Streaming, Interactive, Background)
  - Terminal capabilities
- And uses Adaptive Modulation and Coding (AMC) ..

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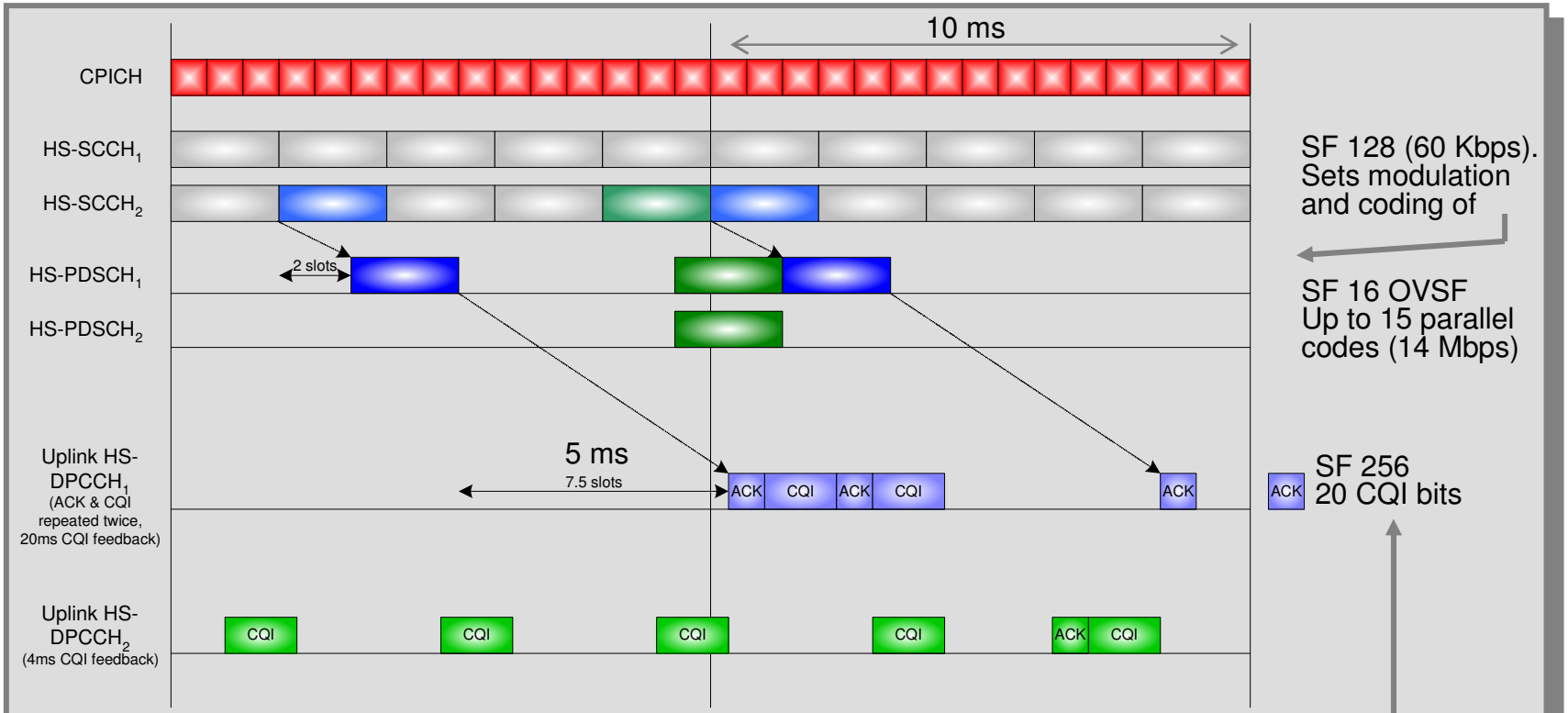
Essentials 3: AMC

- Instead of adjusting the transmit power, change the “coding gain”
  - Send more user data and less error protection for good channels
  - Use higher order modulation to increase the data rate
    - use higher FEC coding rates
    - optional 16-QAM modulation
- Use multiple OVSF codes allocated to a single user
  - Send data over up to 15 codes simultaneously
  - Number of codes depends upon UE capability
- To schedule and set modulation Node B needs fast Channel Quality Indication (CQI) from terminal...

Essentials 4: CQI, and HS channels



- UE measures the SIR of the CPICH and calculates best data rate
  - Aim to receive data with <10% PER
  - Consider UE capability
- CQI reported to Node B via dedicated UL channel HS-DPCCH

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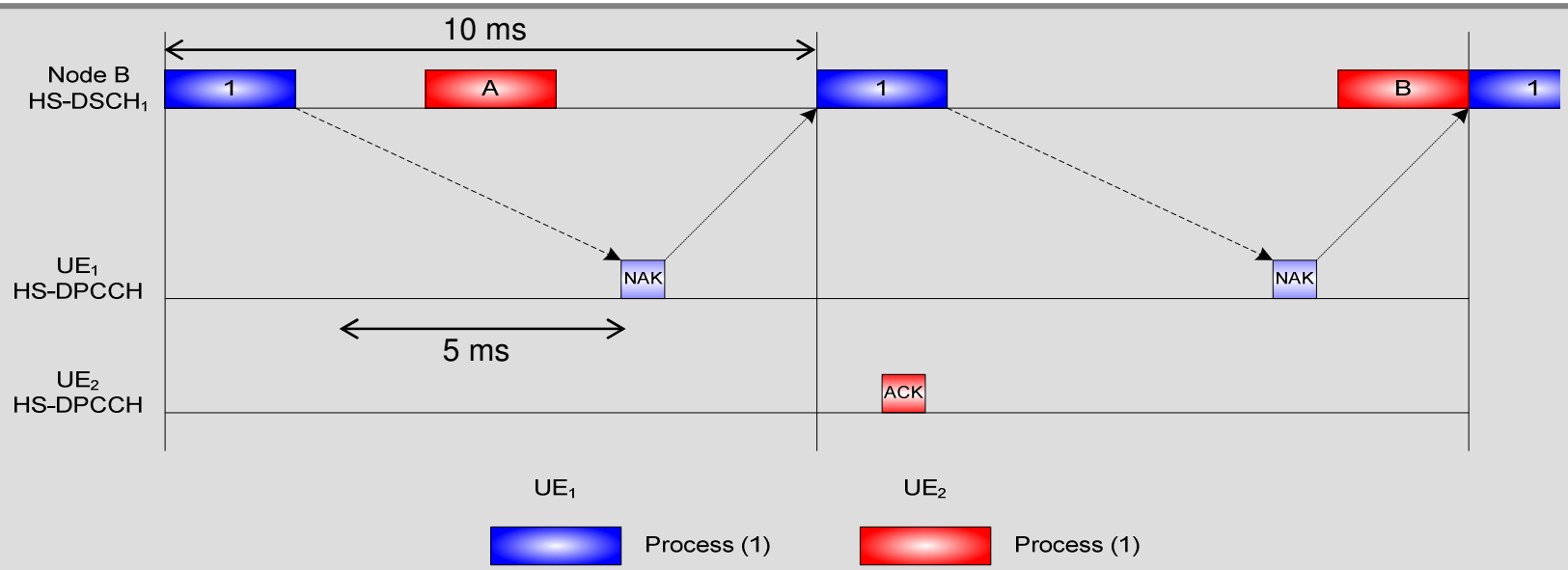
Essentials 5: HARQ re-transmission



- Hybrid-ARQ scheme complements AMC by allowing for rapid re-transmission of erroneous packets
- Instead of discarding the packet (as in R99), combine multiple transmissions
  - Maximises the chance of successful reception
  - Requires additional buffering in the UE Layer 1
- Node B handles re-transmission (RNC for R99) to minimise packet delays

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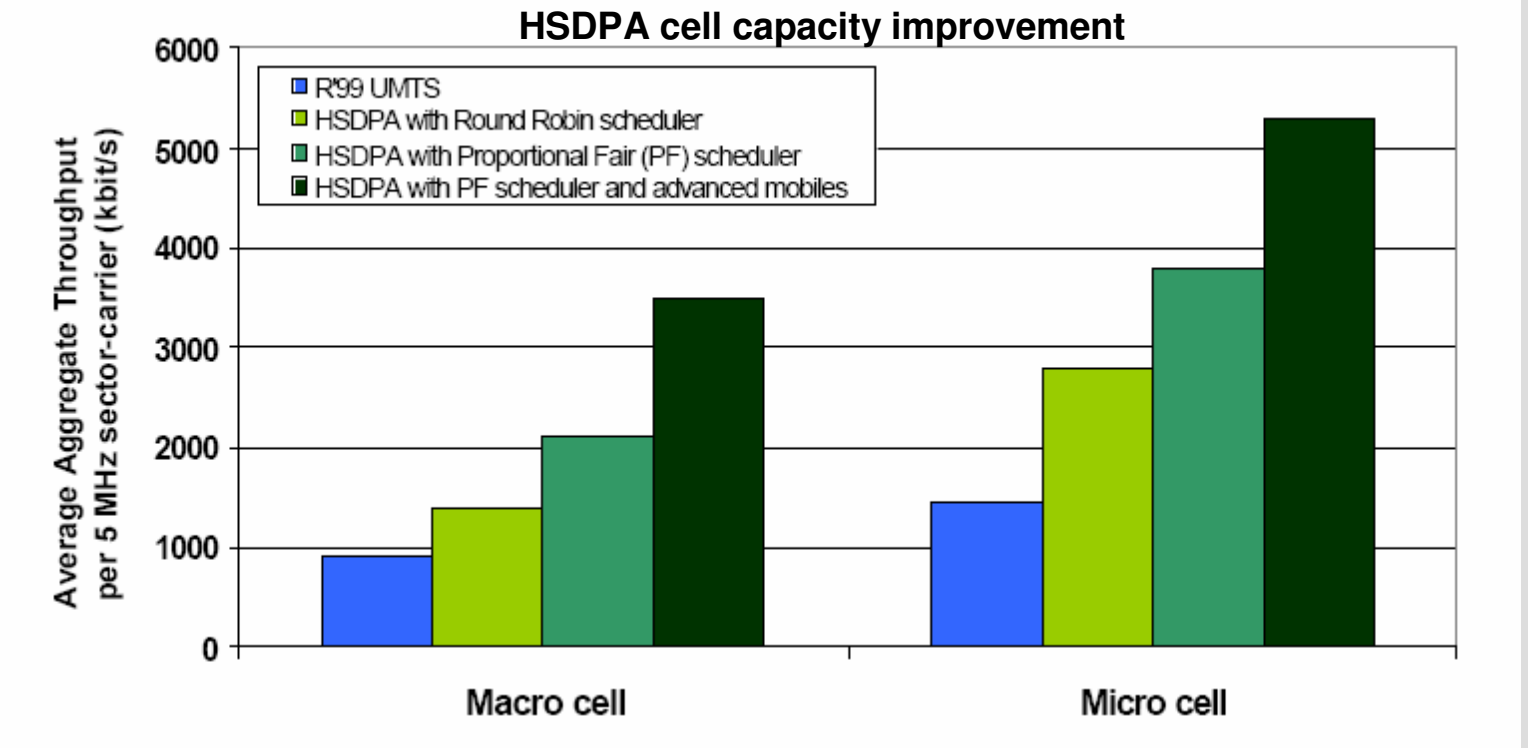
Essentials 6: HSDPA vs WCDMA



- 2-3 times cell capacity
- Low latency and fast download
- Wireless “Broadband” for user

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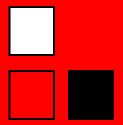
HSDPA Implementation

Principal Issues:

- Need better SNR for higher rates
- Better RF
- Equaliser not Rake
- HARQ buffers
- HS-MAC



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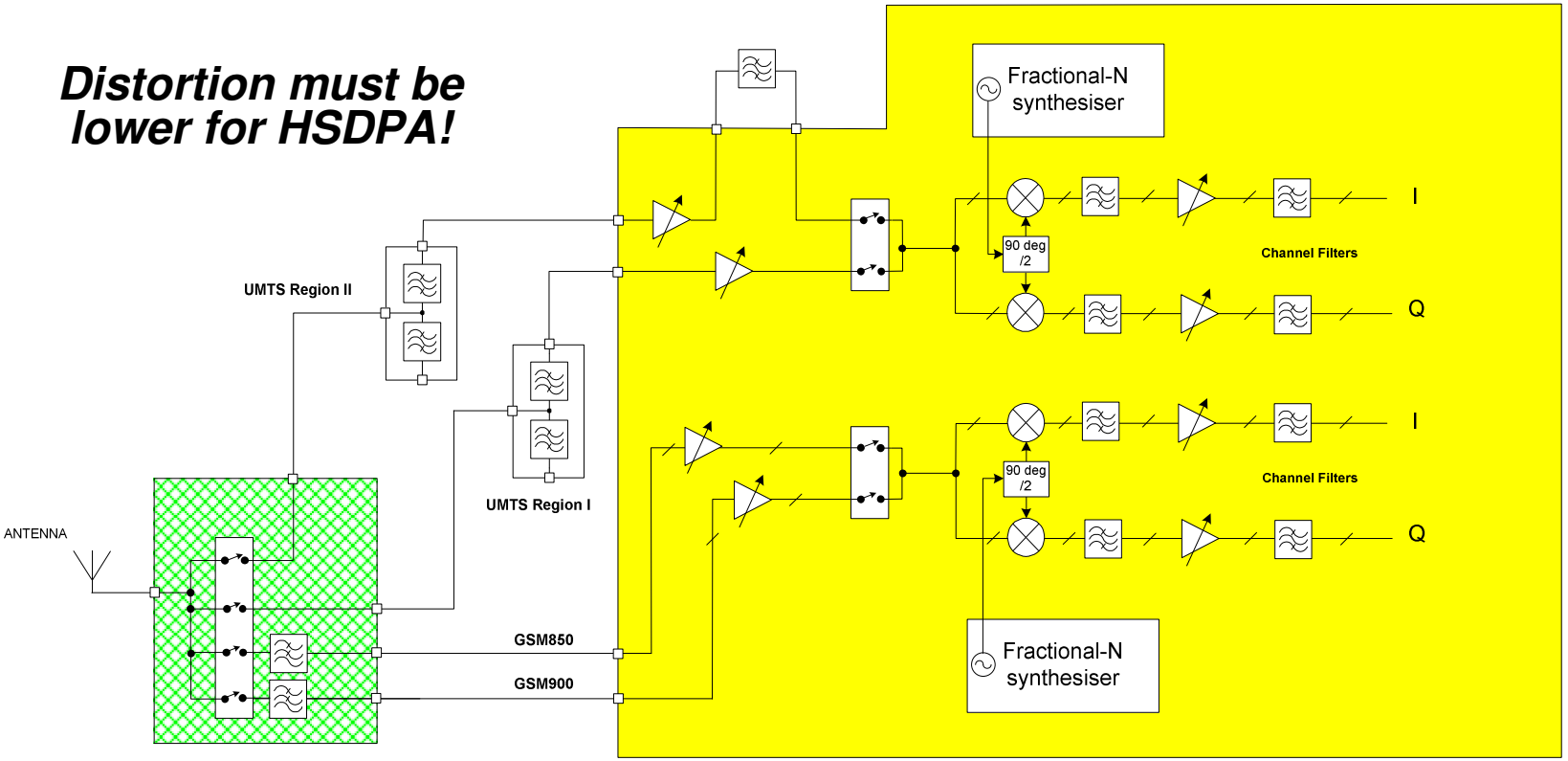
RF considerations

Distortion must be lower for HSDPA!



- Direct conversion receiver gives competitive design – low BOM
- But must minimise DC offset – **even more important with HSDPA**
- Trick is to remove DC component but retain fast settling on gain step
- ***UbiNetics has just started an HSDPA RF chip development with Renesas***

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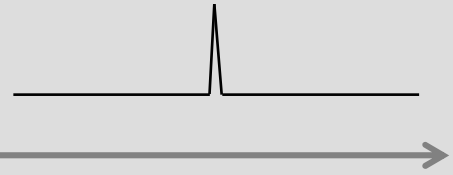
Equaliser

- Rake receiver combines multiple paths
  - Each path adds noise – Multi-Access Interference
  - Worse at low SF – OVSF correlation worse

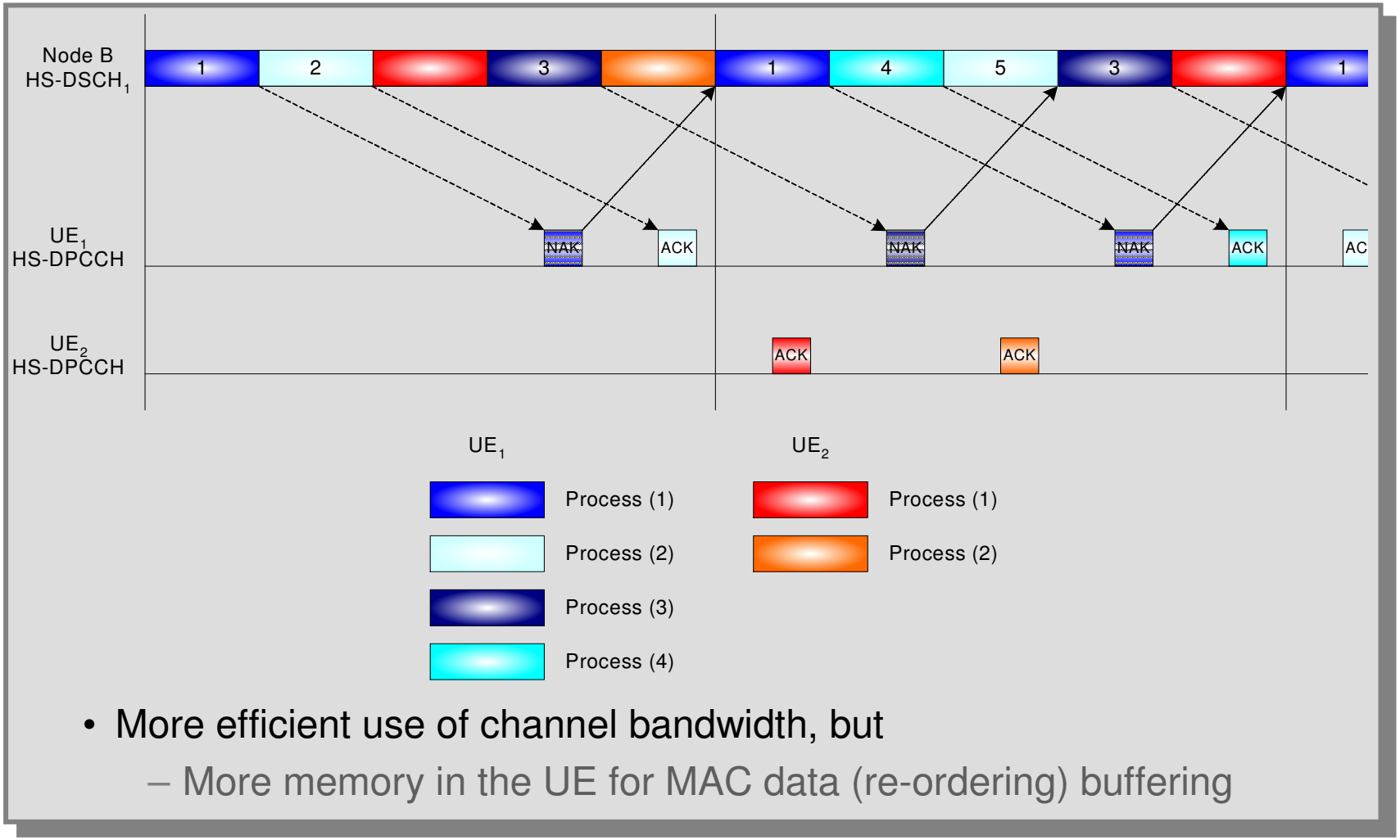


- Equalisers particularly suited to HSDPA
  - HSDPA targeted at low mobility, high bandwidth users
  - Relatively static channel – plenty of time for equaliser to adapt
  - QAM-16 requires good SNR
- Equaliser measures the channel profile
  - Applies an inverse of the channel to the received data
  - No multi-access interference – improved Rx SNR!
- Increased UE complexity
  - Complex calculations to evaluate equaliser tap weights

- G-RAKE (?)
- Linear filter HS-PDSCH receivers:
  - LMS-based equaliser
  - MMSE based equalisers

H-ARQ re-transmission

Multi-Channel



- More efficient use of channel bandwidth, but
  - More memory in the UE for MAC data (re-ordering) buffering

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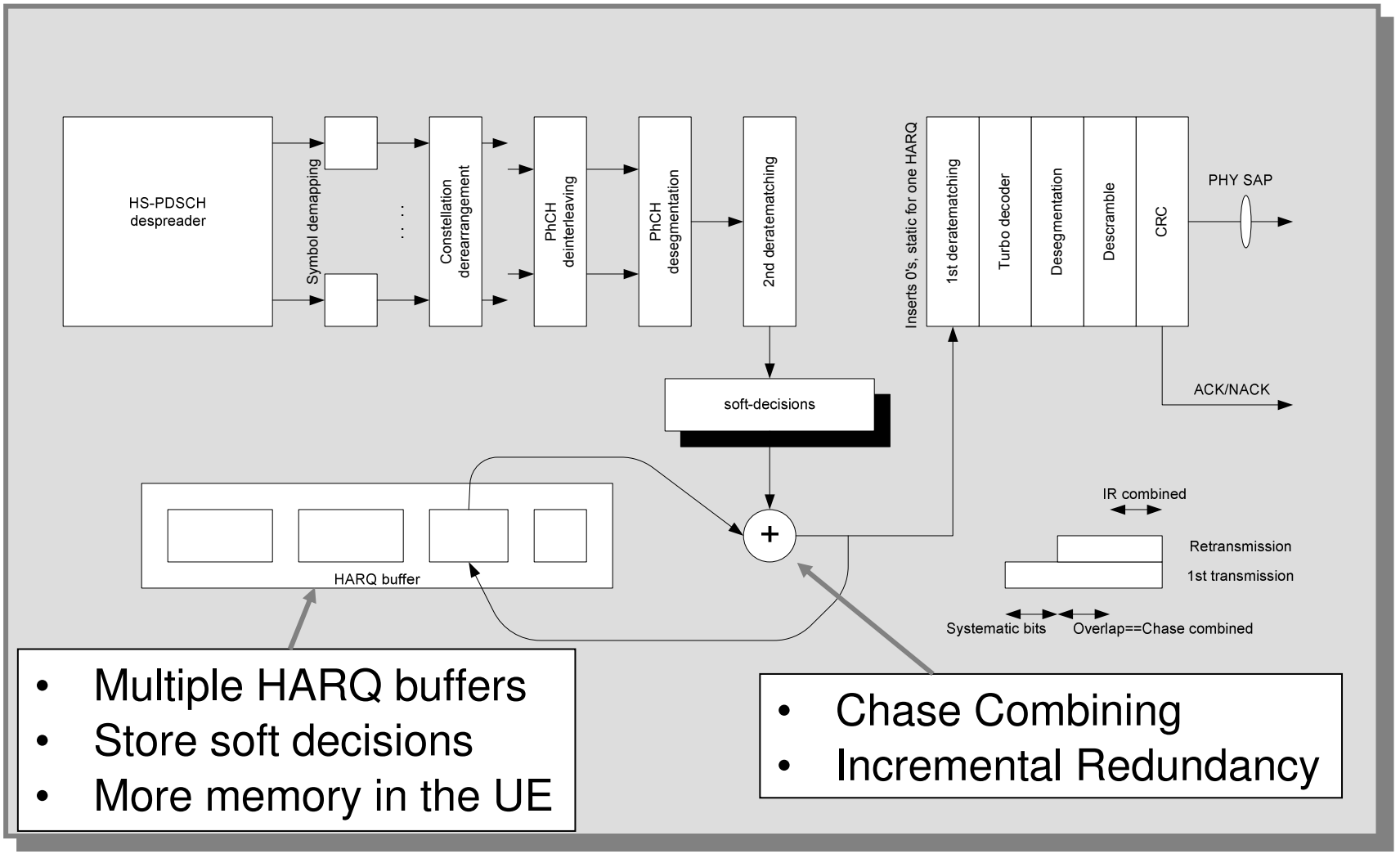
H-ARQ Combining

Bit rate processing (Turbo) block with soft-decision combiner



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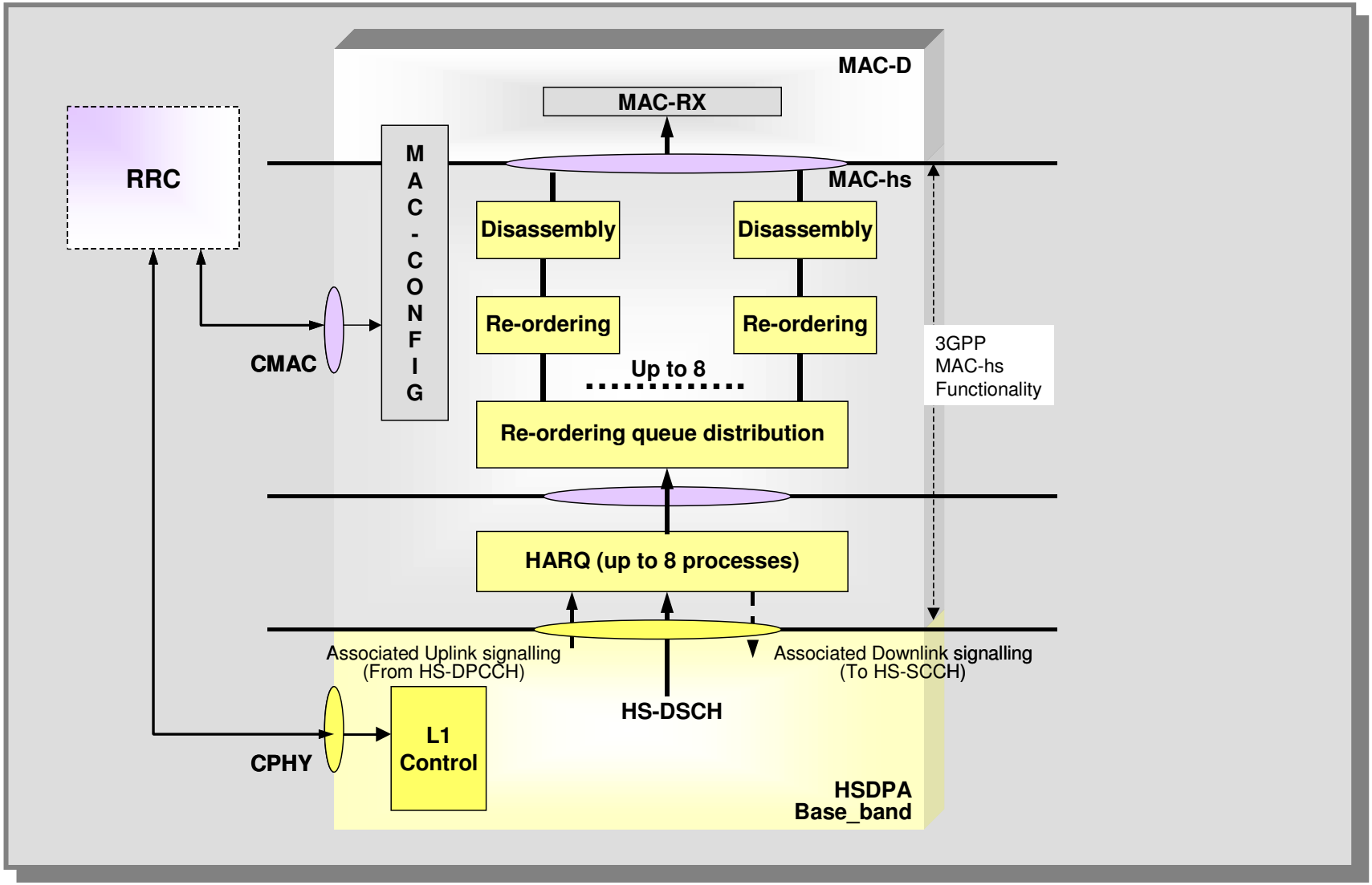
HS-MAC



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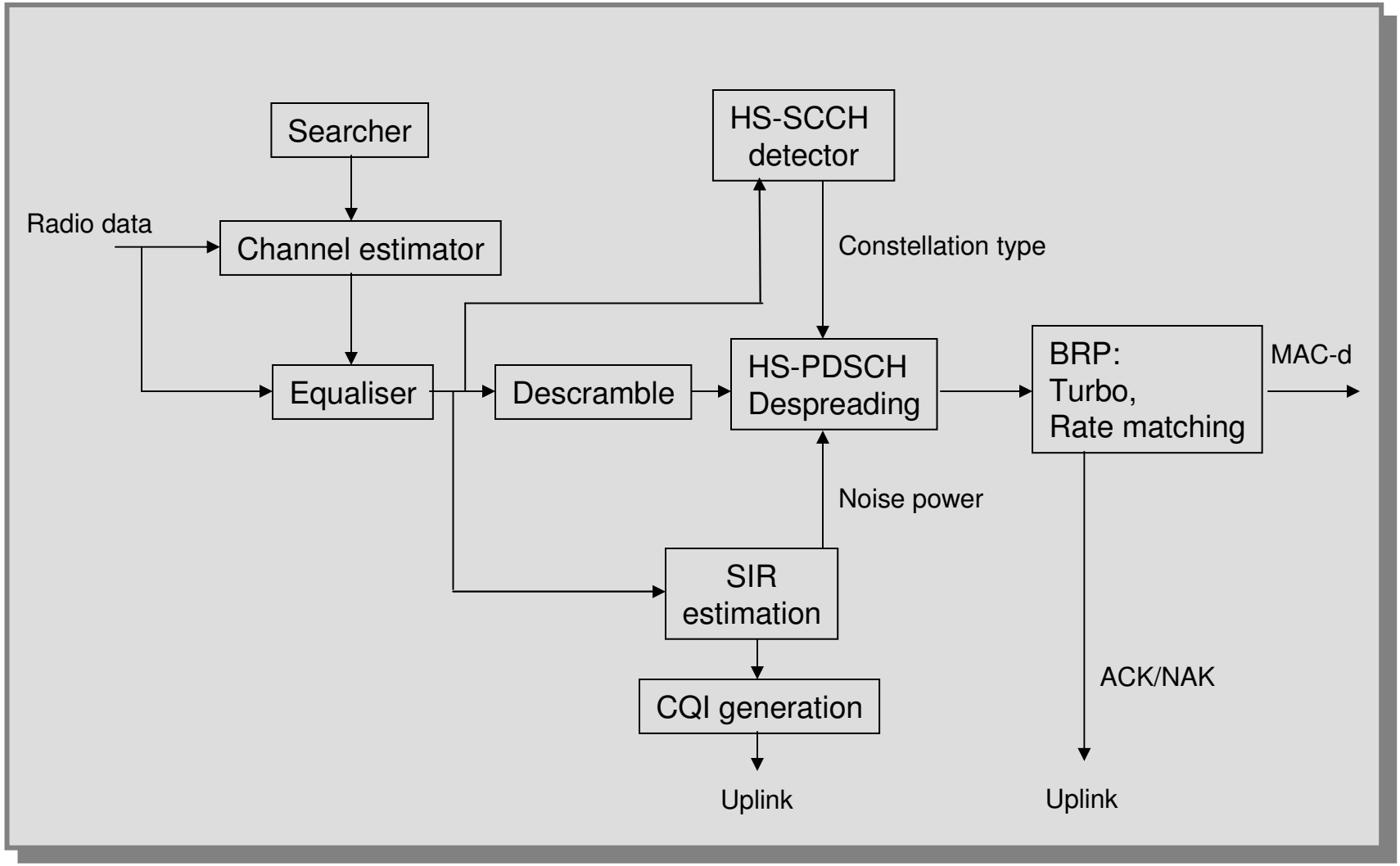
HSDPA receivers

Generic HSDPA L1 architecture



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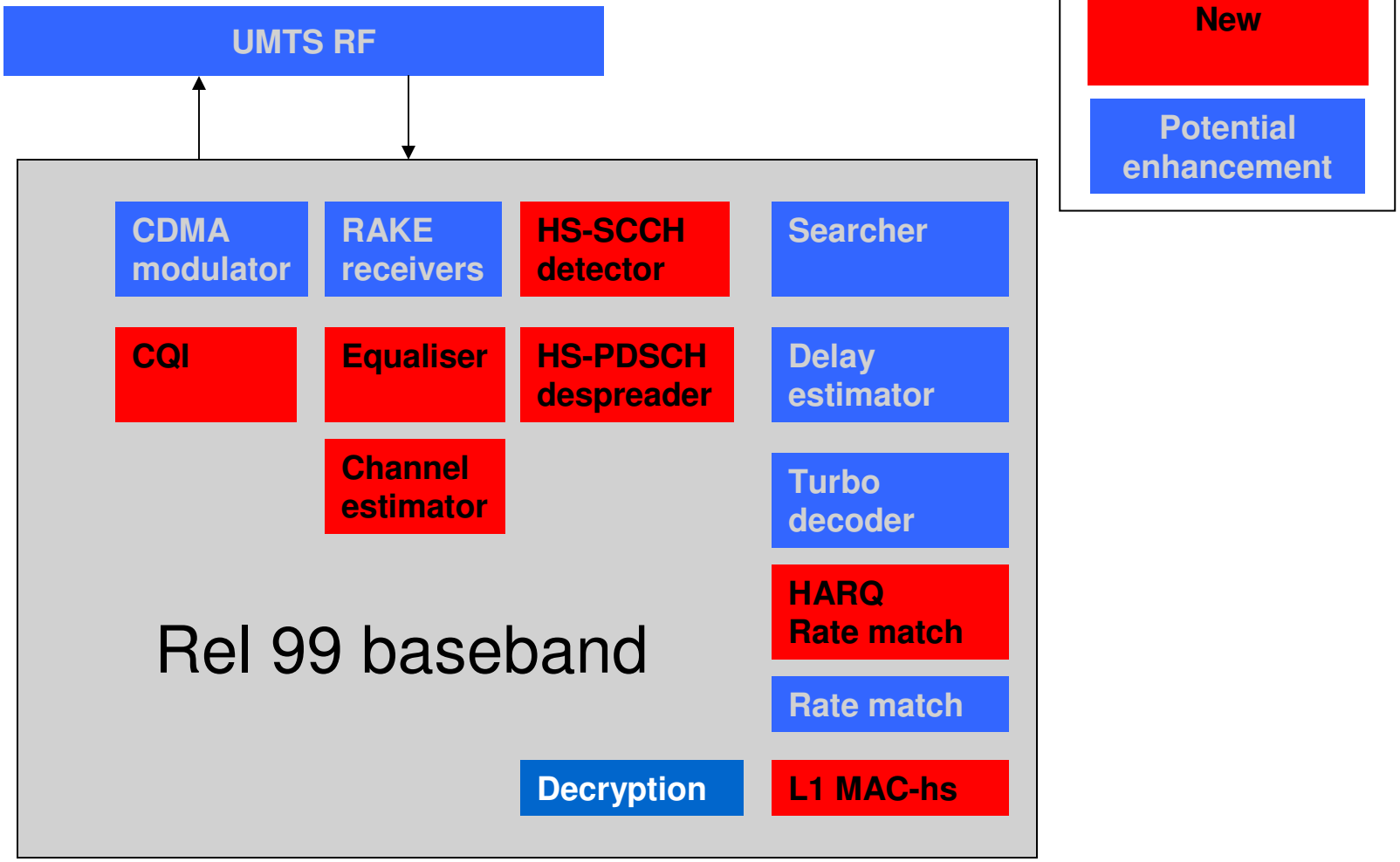
WCDMA Baseband migration

Typical block diagram for HSDPA entities



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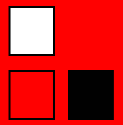
WCDMA Baseband migration

Typical HW/FW and SW split options

Entity	HW	FW	SW
Channel estimator	x		
Equaliser	x	x	
HS-SCCH detector	x	x	
HS-PDSCH de-spreader	x		
CQI generator		x	
CPICH SIR calculator	x	x	
Uplink HS-PDCCH	x		
BRP & HARQ	x	x	
MAC-hs	x	x	x

And the Up Link?

That is another story!



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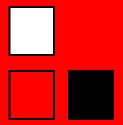
Thank you

Questions?



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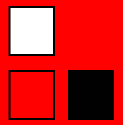
Rel 5 Capability Classes

TABLE 1 TWELVE CATEGORIES OF HS-DSCH-CAPABLE TERMINALS.

Category	Maximum number of supported HS-DSCH codes	Minimum inter-TTI interval	Number of soft values in terminal's hybrid ARQ buffer	L1 peak rate [Mbit/s]	Modulation schemes
Category 1	5	3	19,200	1.2	16QAM, QPSK
Category 2	5	3	28,800	1.2	16QAM, QPSK
Category 3	5	2	28,800	1.8	16QAM, QPSK
Category 4	5	2	38,400	1.8	16QAM, QPSK
Category 5	5	1	57,600	3.6	16QAM, QPSK
Category 6	5	1	67,200	3.6	16QAM, QPSK
Category 7	10	1	115,200	7.3	16QAM, QPSK
Category 8	10	1	134,400	7.3	16QAM, QPSK
Category 9	15	1	172,800	10.0	16QAM, QPSK
Category 10	15	1	172,800	14.0	16QAM, QPSK
Category 11	5	2	14,400	0.9	QPSK
Category 12	5	1	28,800	1.8	QPSK



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