Project	IEEE 802.16 Broadband Wireless Access Working Group
Title	Soft Error Correction Coding techniques and multilevel modulations for BWA
Date Submitted	9 September, 1999
Source	Moshe Ran TelesciCOM, LTD 6 Hamachtesh st. Holon ISRAEL, 58810 Voice: +972-3-5589595/208 Fax: +972-3-5589092 E-mail: Mran@telescicom.co.il
Re:	PHY TG Call for contributions IEEE802.16pc-00/03 item (3)
Abstract	The use of error correction coding (ECC) is a mandatory tool for the communication designer when minimizing the system resources of power, bandwidth, delays and complexity. A small improvement in ECC performance can yield a large reduction in overall system cost. Applications of new ECC schemes based on Soft in \Soft out (SISO) algorithms and iterative decoding combined with multilevel modulation provide new opportunities to achieve better and more cost effective design of broadband wireless access (BWA) communication systems.
Purpose	The soft decoding techniques discussed in this document exhibits performance close to theoretical limits. Although different PHY may support different ECC schemes and different modulation schemes, methods as identified herein will provide guidelines for selecting among vendors based on their performance compared to the theoretical limits.
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Release	The contributor acknowledges and accepts that this contribution may be made publicly available by 802.16.

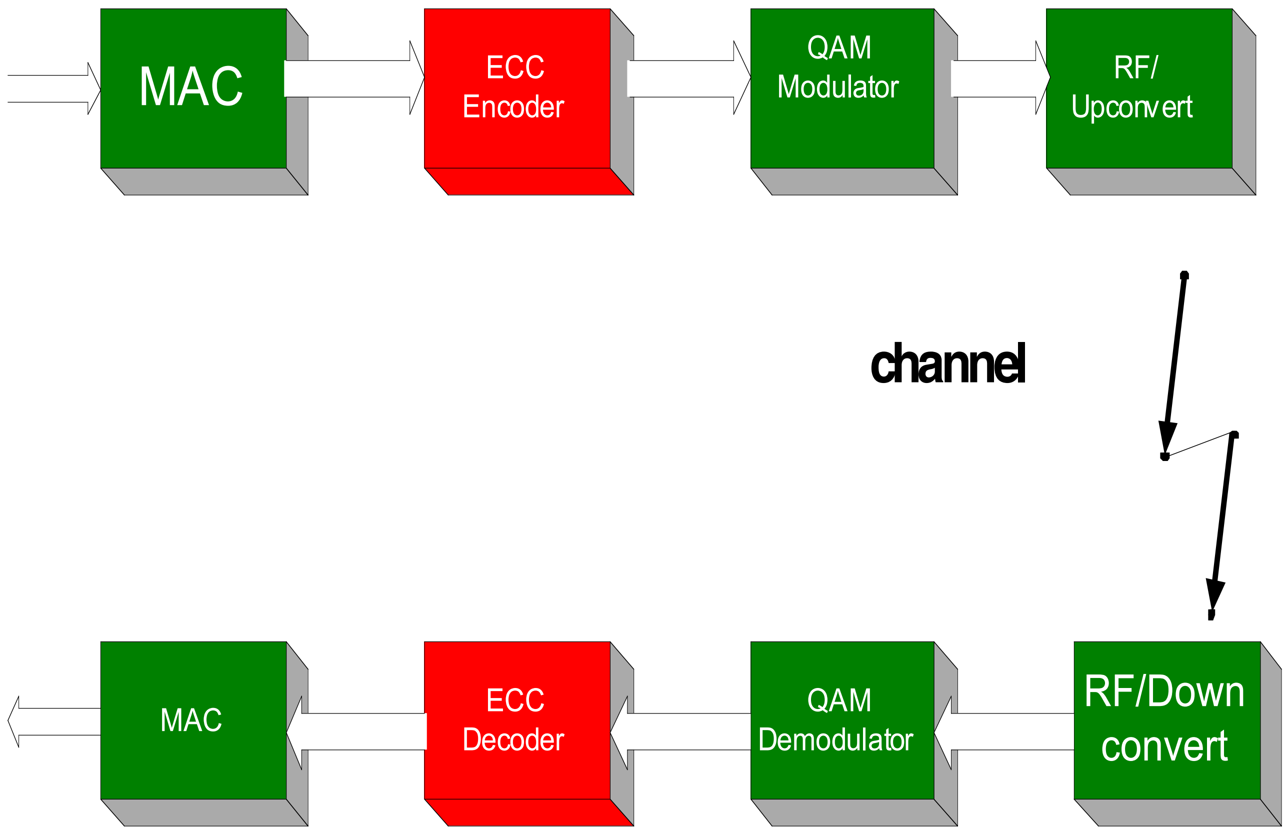
Error correction codes for BWA

Moshe Ran, TelesciCOM Ltd.

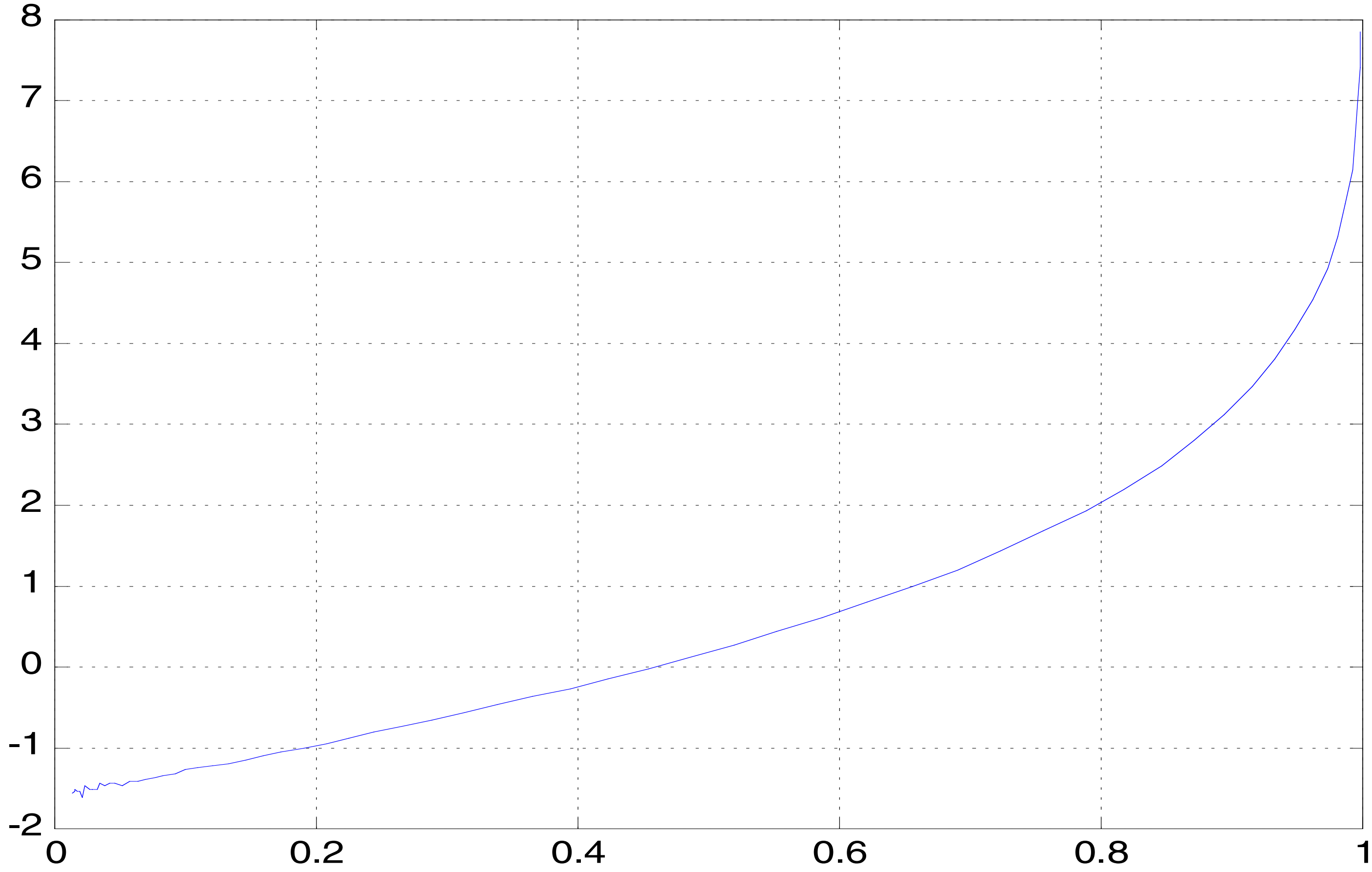
Summary

- Introduction to ECC
- Soft/Hard decoders
- Soft in/Soft out (SISO)
- PHY: M-QAM + Soft decoders
- Applications to BWA

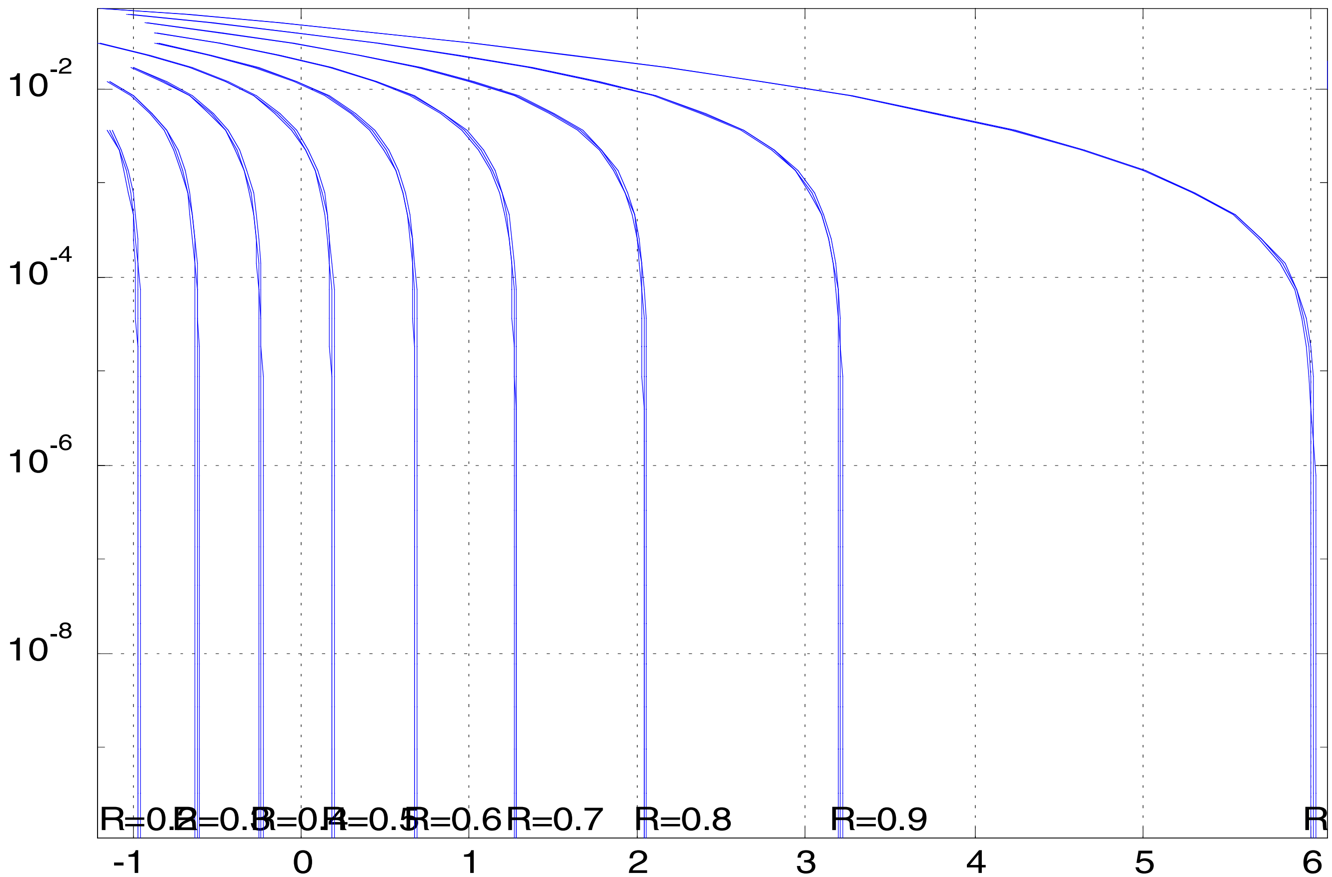
Error Correction Coding



E_b/N_0 vers. R- Shannon limit



Shannon limits for 2PSK



Survey of coding-decoding techniques

- Forward Error Correction (FEC)
- Automatic-Repeat-reQuest (ARQ)

<u>FEC vers. ARQ</u>:

- FEC: a physical layer (PHY) technique
  ARQ: is related with higher logical link layers.
- FEC has a constant throughput regardless of the channel conditions while in ARQ throughput decreases rapidly at an increasing error rate.

Survey of coding-decoding techniques

- **FEC**: no feedback channel required

  ARQ: a feedback channel is required for (ACK\NAC).
- **FEC**: complex coding-decoding scheme to achieve high reliability

  ARQ: very low BER are accomplished using simple codes with good error detection capabilities.
- **FEC** techniques are preferred to ARQ for delay sensitive applications.
- ***Hybrid techniques*** consisting of FEC inner code contained in an ARQ outer code

Survey of FEC techniques

- convolutional codes (viterbi)
- Block codes: Hamming, BCH, RS, RM(r,m)
- concatenation of convolutional (inner code) /RS (outer code).
- product-codes
- Turbo-codes (TC) and Iterative decoding (SISO):

CTC = convolutional TC, BTC=block TC

Hard/Soft decision decoding

• Soft decision (SDD) decoder:

- reliability vector (soft, channel info.),
- hard detected symbol-by-symbol vector

• Encoder: SDD with the same code parameters provides up to 3 dB improvement over HDD !

• Optimal SDD's exist for:

- convolutional code (SOVA)
- repetitions, parity-check, Hamming, simplex, RM

• Sub-optimal SDD: GMD and Chase algorithms

• Complexity: Optimal SDD are impractical for long codes with exponential growth of complexity

BTC-CTC characteristics

- New concept: SISO + Iterative decoding
- Updating soft information: “extrinsic” info.
- Structure: based on simple components

codes

- CTC: error floor, large interleavers,
- small free-distance
- BTC: no error floor, best high rate codes for

BER 10E-3 to 10E-9

BTC Key Features

- 0.5 - 3 dB within the limits established by Shannon for AWGN channel
- Large coding gain: 8-10 dB
- High spectrally efficient modulations
- Flexibility: complexity\performance, wide block length, wide code rate
- State-of-the art SDD for the components codes: fast convergence & low complexity, short delays, near ultimate bounds

ECC for BWA Key Issues

- Channel model, BW/Power efficiency
- BER levels several orders poorer than wireline
- Mixture of random and burst errors
- ECC requirements for voice\data\video differ
- Packet size:ATM, MPEG, IP

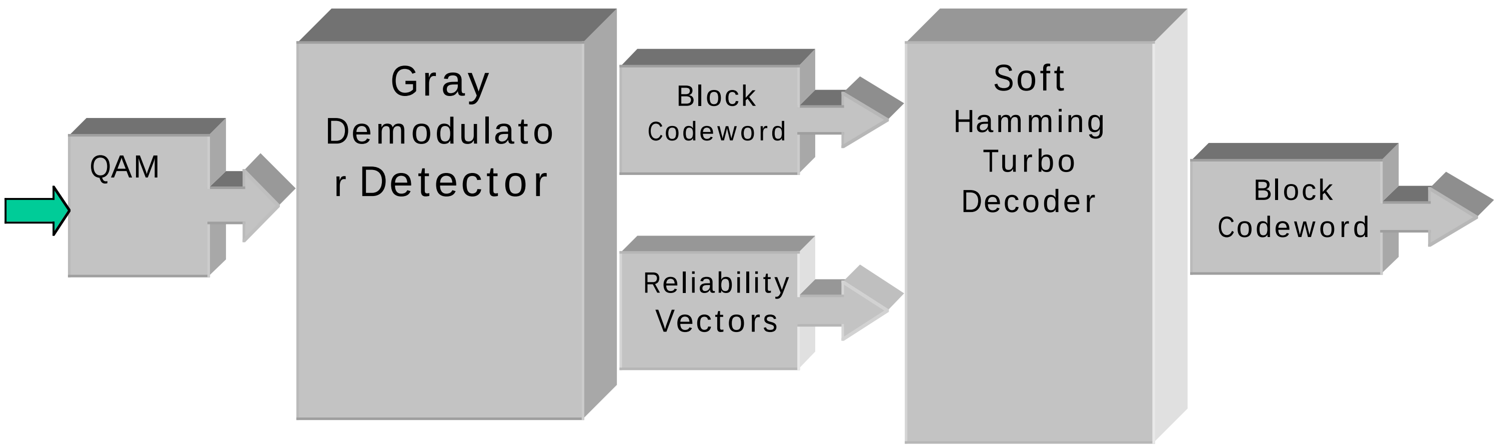
Improved PHY for BWA

- Modulation types
  - BPSK, QPSK,OQPSK, GMSK
  - M-QAM
- Spectral efficiency 1 to 8 b/s/Hz
- BTC \ SDD code rates: 0.3 - 0.9
- Variable block length including
  - ATM, IP, short packets

Benefits of improved PHY to BWA

- Improve Performance and QoS
- Lower Tx Power\Smaller Antennae
- Increased range
- Better cellular deployment
- Flexibility: various packets size including all leading data protocols

M-QAM + BTC Decoder



CTC/ BTC for ATM

CODE RATE	Shannon Bound@ FER=1e-5 [dB]	E_b/N_0 dB @ RS-Viterbi FER=1e-5	E_b/N_0 dB @ CTC FER=1e-5	E_b/N_0 dB @ BTC FER=1e-5
(7/8) * (57/73)= 0.683	1.16	5.8	3.7	2.8
(6/8) * (57/73) = 0.586	0.6	5.5	3.1	2.4
(4/8) * (57/73) = 0.390	-0.28	4.1	2.5	1.6

Concluding Recommendations

- SISO decoders such as BTC\CTC are suggested for FEC of BWA
- FEC should support high coding gain
  - Spectral efficiency 1 to 8 b/s/Hz
  - Variable block length including:

    ATM, IP, MPEG, short packets

particular decoder implementation: SDD\HDD do not affect interoperability!