Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [HARQ for High QoS Applications of BANs]

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Abstract: [The presentation shows the potential of HARQ for proving high QoS applications for BANs.]

Purpose: [Call for participation for a common wideband architecture for on-body BANs.]

HARQ for High QoS Applications of BANs

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Introduction

Dependable real-time communications is critical for medical applications

- challenging as the radio channel can be time variant and/or experience deep fades if the subject moves.
- The channel must be shared among several devices.

QoS in real-time communications

- Hard real-time systems: late delivery cannot be tolerated.
- Soft real-time systems: a specified low probability of late delivery is tolerated (performance degradation).

QoS in real-time communications

Types of traffic

- Guarantee traffic: every frame in the stream is guarantee to arrive before a deadline (latency).
- Statistical traffic (statistical guarantees): a certain percentage of frames might miss a deadline (latency or error).

Guarantees in the context of BANs are probabilistic due to the radio channel

- A specified QoS is guarantee with certain probability (connected to average behavior)
- Such specified QoS can be minimum throughput and bounded end-to-end delay (latency)
- Thus, in BANs we can guarantee a minimal average throughput and minimal average end-to-end delay.

QoS in BANs

QoS parameters:

- minimal average throughput and minimal average end-to-end delay

QoS in BANs is mostly affected by the radio channel

- varying error rate operation

Another difficulty is the channel access (medium is shared), scheduling (preemptive) and prioritization (MAC or upper layer).

In order to provide high QoS in BANs

- it is necessary to optimize PHY and MAC jointly.
- HARQ can be a practical approach to meet high QoS.

Error Control in BANs

ARQ mechanisms are relatively simple for error control

- although throughput falls rapidly with increasing channel error rate and/or end-to-end (round trip) delay.

FEC mechanisms offer constant throughput k/n

- although packets detected in error and cannot be corrected are discarded.
- High reliability is achieved by long codewords increasing complexity, power consumption and latency.
- This makes sense in bad channel conditions only.

Adaptive Error Control in BANs

Combine ARQ and FEC: HARQ

- sort of join optimization PHY and MAC.

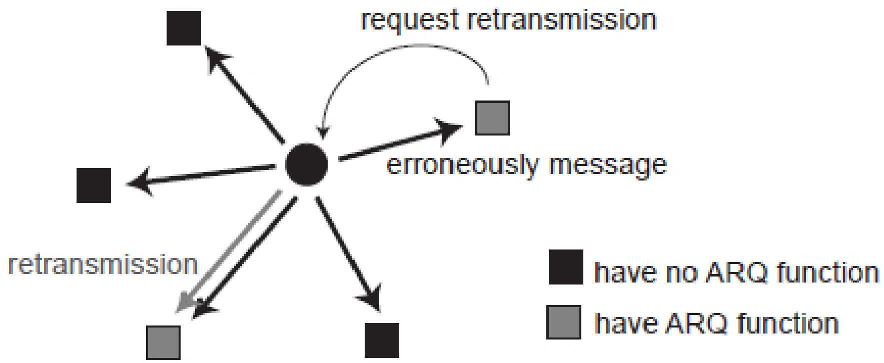
HARQ offers

- FEC subsystem reduces frequency of retransmissions by correcting error patterns that occur most frequently.
  - ▷ *increasing system throughput while keeping low complex code design.*
- Receiver requests retransmission when less frequent error patterns occur.
  - ▷ *increasing system reliability.*

Proposed topology

In order to coexist high QoS and lower QoS applications

- In the star topology, devices use channel coding
- but only high QoS devices are HARQ enable



Proposed HARQ Scheme

HARQ Type II

- Only parity bits are sent is some retransmissions.
- Erroneous packets are not discarded. Decoder might employ previously received packets.

Characteristics

- Coding overhead is low. Suitable for bursty (time-varying) channels.
- Upper limit in the maximum number of retransmissions (delay within deadline or latency).

HARQ Type II

Benefits

- It continuously adapts to instantaneous channel conditions
- The combination of FEC and ARQ strategy is initiated when channel conditions are bad
- If the channel conditions are not bad (time varying and deep fades), a negligible number of retransmissions are required.
- Therefore, the system employs the required amount of redundancy and retransmissions suitable for current channel conditions, saving energy and system resources, while keeping high throughput and reliability.
- An attractive adaptive error control mechanism for BANs.

HARQ Type II Generic flow

- **CRC for error detection $Q = C_0(D)$. FEC for error correction $P = C_1(D)$.**

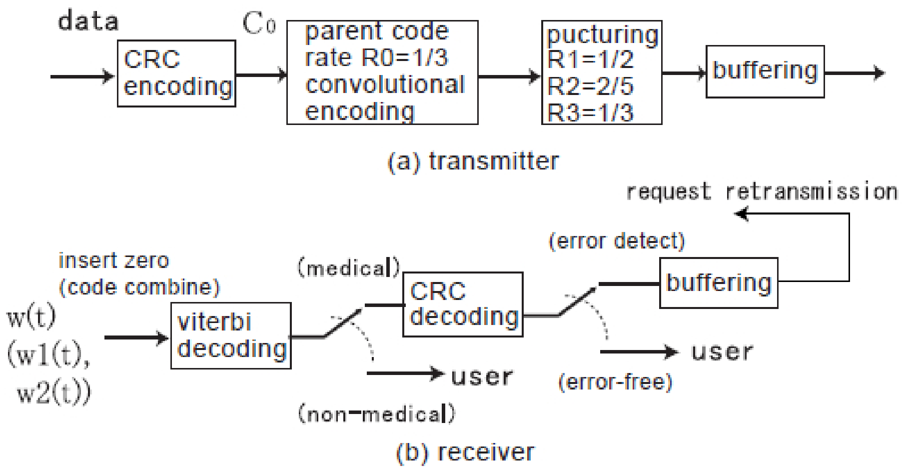
1 : *Tx sends* (D, Q)
if *Rx determines message is error free using* C_0 **then**
  Rx accepts message and passes it to the MAC
else
  Rx sends a NACK
end if
2 : *Tx sends parity bits* (P, Q')
if *Rx determines message is error free using* C_0 *and* C_1 **then**
  Rx accepts message and passes it to the MAC
else
  Rx sends a NACK
  go to 1) or 2)
end if

Proposed HARQ Schemes

We are studying three candidates (finite persistence)

- Incremental redundancy with rate compatible punctured convolutional codes (RCPC)
- Invertible half rate coding
- Concatenated coding

HARQ-RCPC



- Transmission starts with the highest code rate
- If the received codeword is detected in error (CRC), a retransmission is requested. The transmitter sends an incremental redundancy codeword.

HARQ-RCPC Parameters

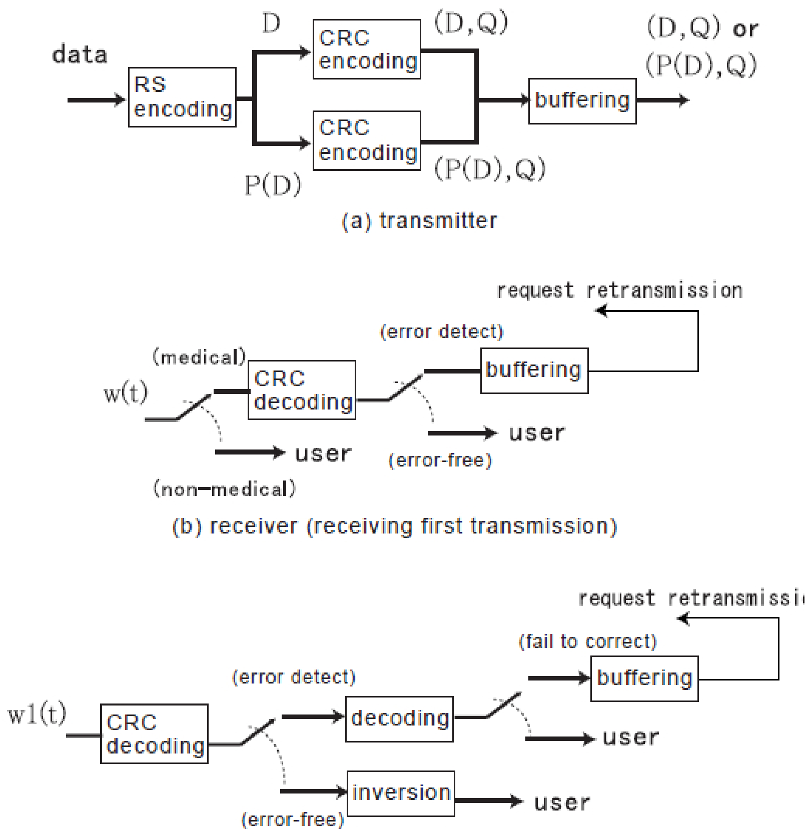
- HRO-RCPC codes of parent code rate 1/3

K	(g_0, g_1, g_3)	$P_{2/3}$	$P_{1/2}$	$P_{2/5}$
7	(133,165,171)	1 1 0 0 0 1	1 1 0 0 1 1	1 1 0 1 1 1

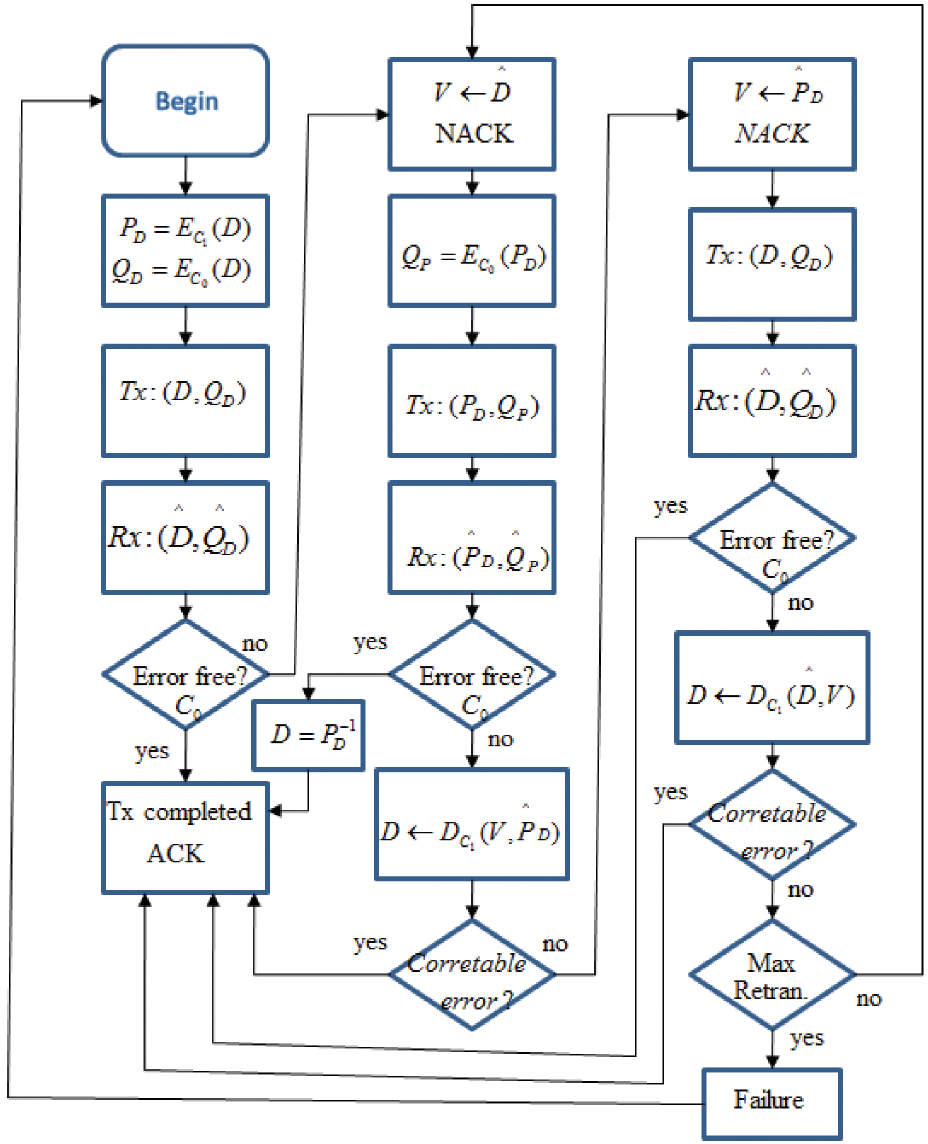
- Numerical evaluation based on UWB-2PPM, short pulses and CM3, CM4 of TG6 channel models

HARQ-Invertible coding

- It is based on half rate systematic RS codes. A code is said invertible when only knowing the parity bits, the information bits can be determined by an inversion process.



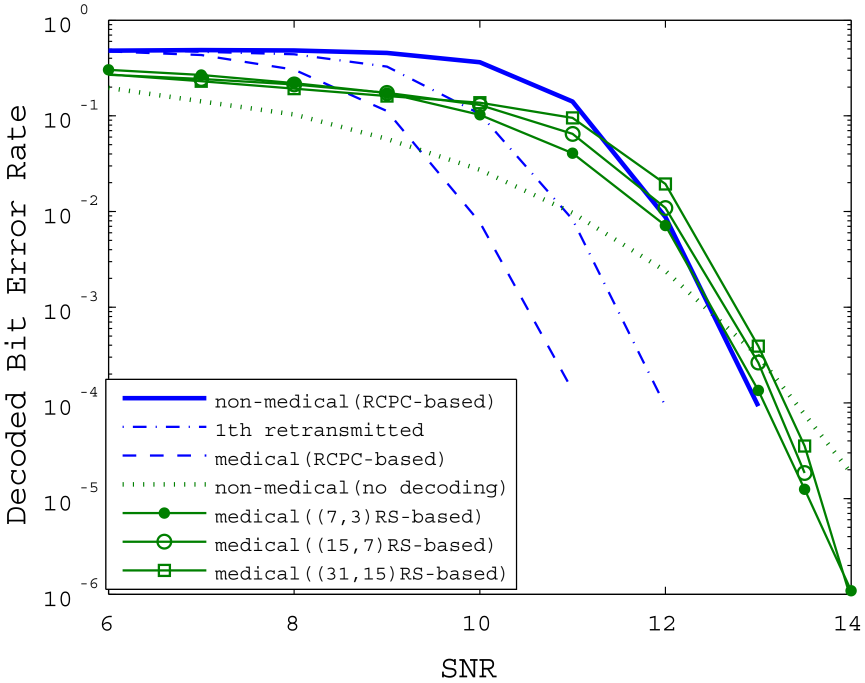
Flow Diagram HARQ-Invertible coding

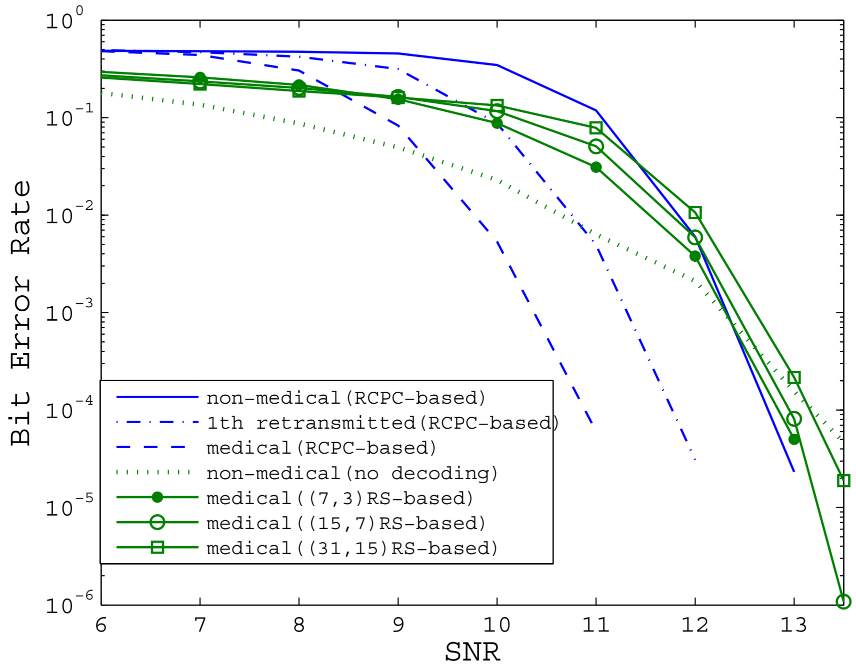


Numerical evaluation

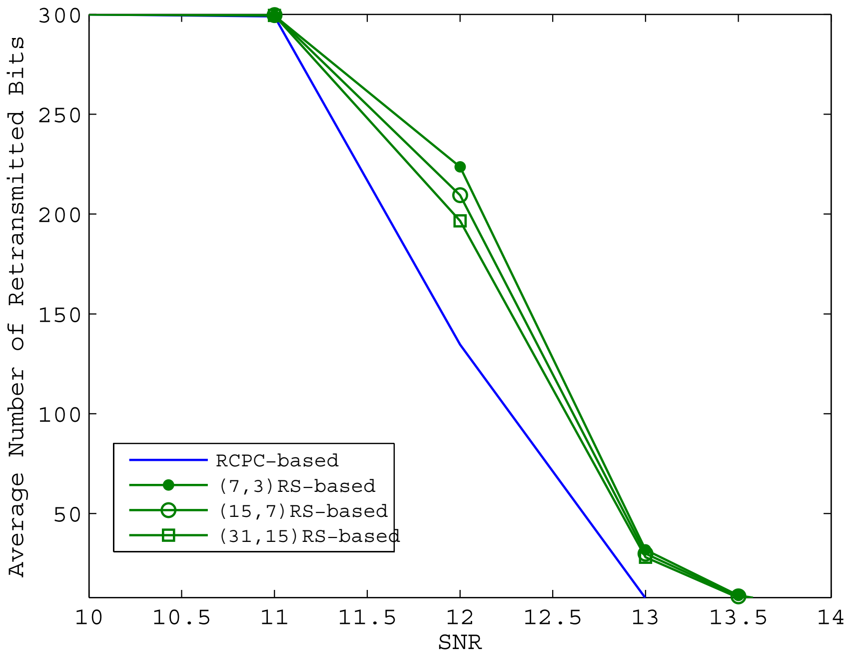
Channel	IEEE802.15.6 CM3 and CM4
Modulation	2PPM
Demodulation	Energy detection
Pulse shape	modulated RRC
Pulse duration	2 nsec
Bit rate	4 Mbps
CRC	CRC-CCITT parity length 16 bits
FEC (RCPC-based)	RCPC codes constraint length K=7 parent code rate 1/3 Code rates : R_k=1/2,2/5,(1/3)
FEC (RS-based)	RS codes GF(2^3),(7,3)RS codes GF(2^4),(15,7)RS codes GF(2^5),(31,15)RS codes Code rates : 1/2
Decoding	RCPC-based : Hard Dicision Viterbi decoding RS-based : Euclid Algorithm
Block length (containing CRC)	RCPC codes: 316 bits (7,3)RS codes: 312 bits (15,7)RS codes: 314 bits (31,15)RS codes : 316 bits
Max. No of transmissions	RCPC-based : 3 RS-based : 2

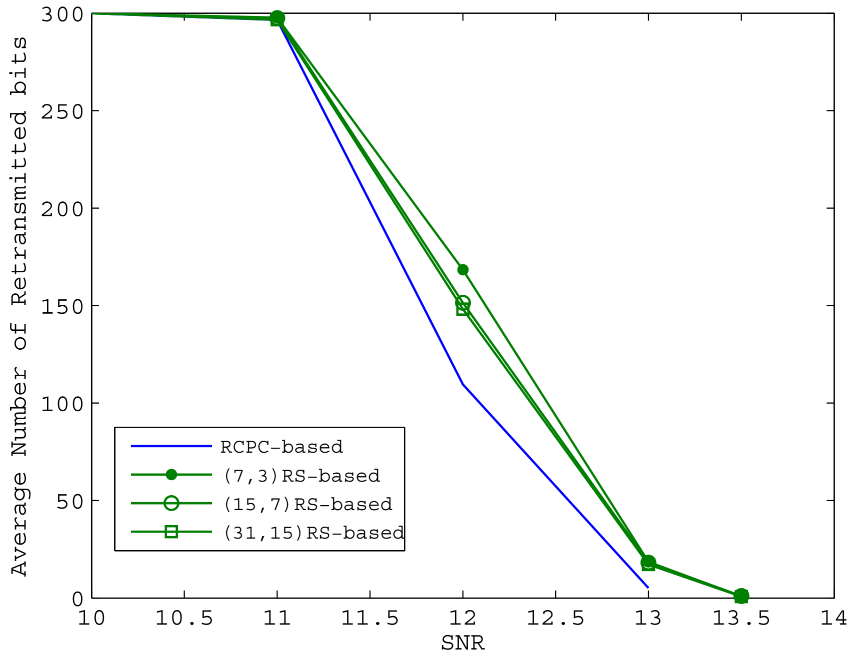
Numerical evaluation: CM3 and CM4



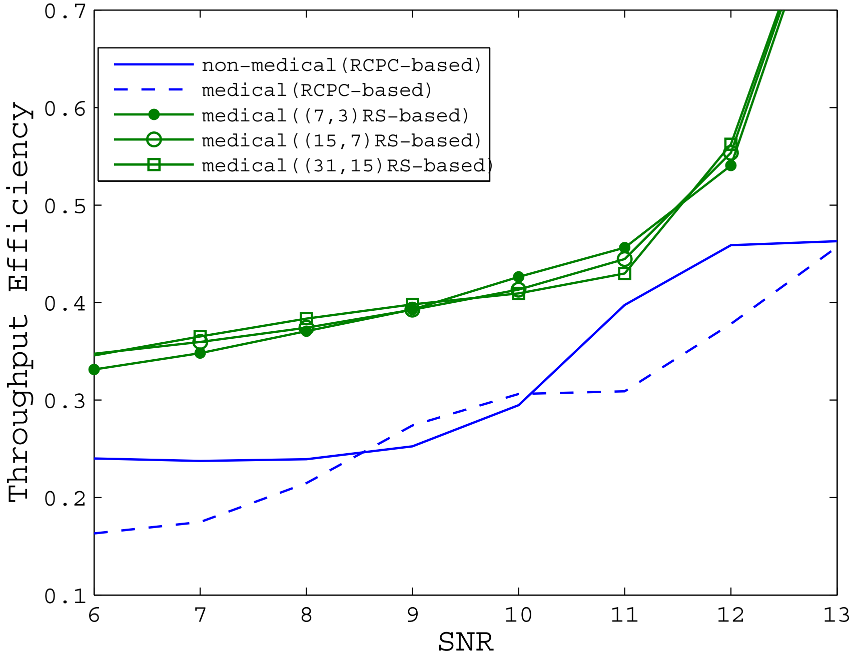


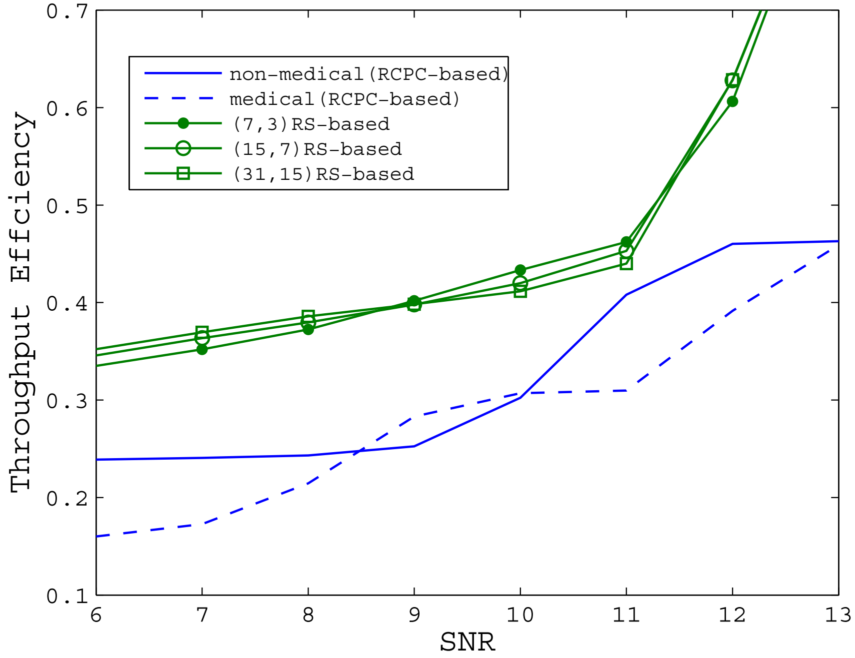
Numerical evaluation: CM3 and CM4





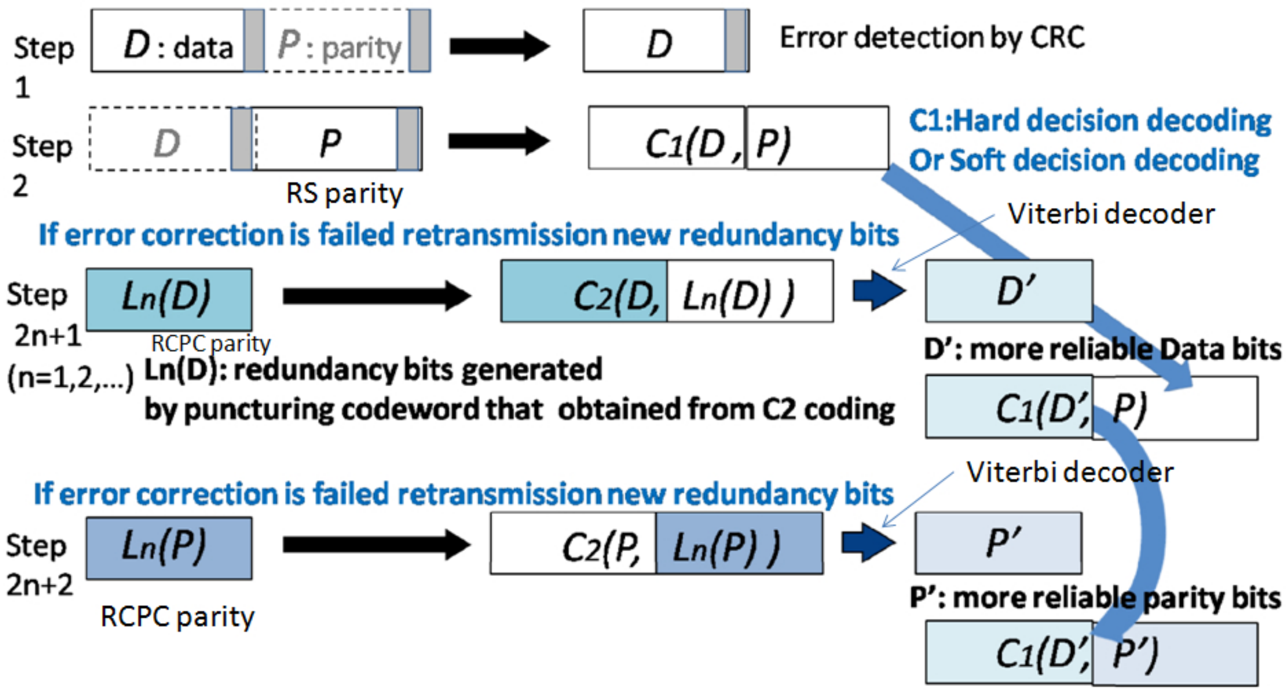
Numerical evaluation: CM3 and CM4





HARQ-Concatenated coding

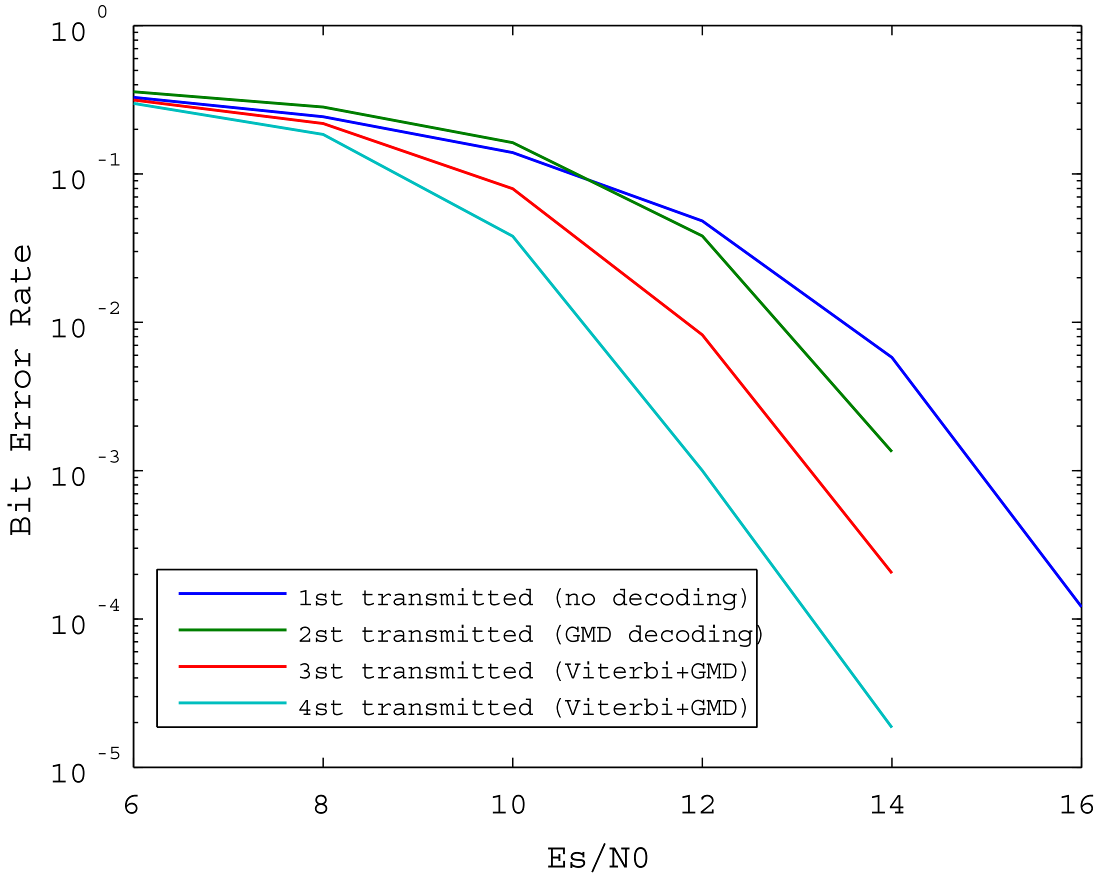
- Inner codes: systematic RS(n,k). Outer codes: RCPC codes.



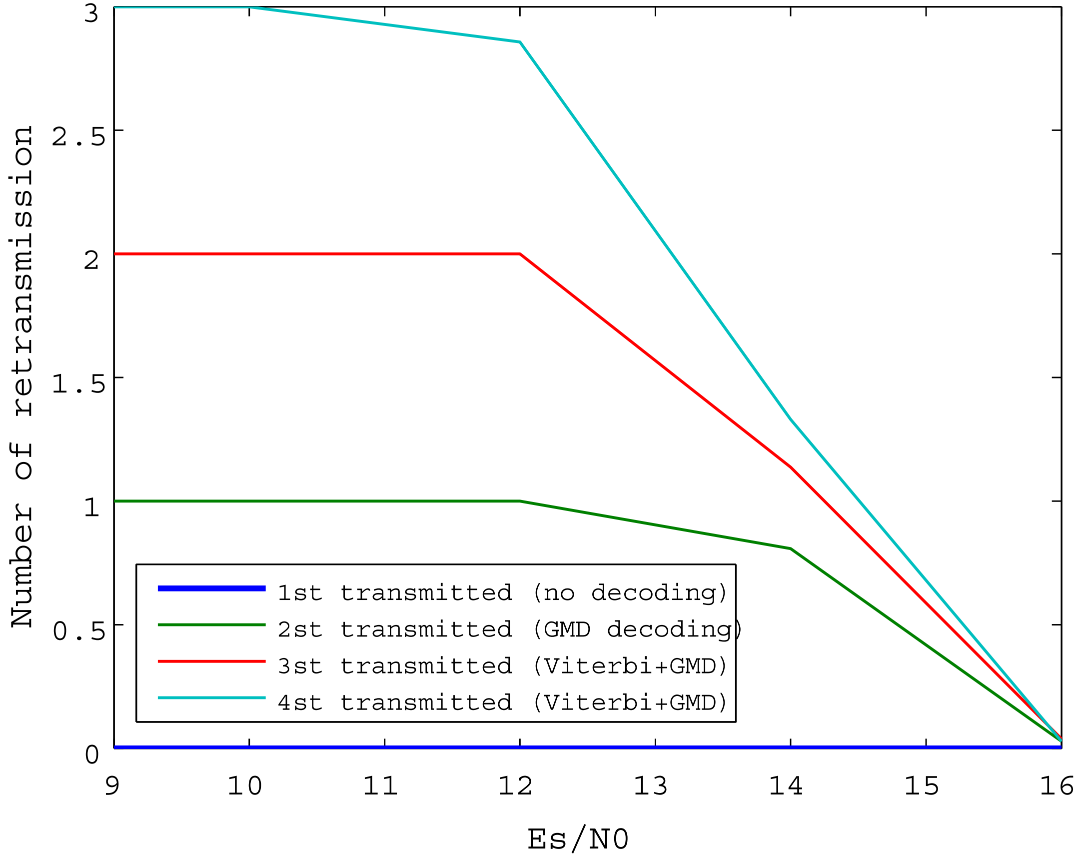
Numerical evaluation

Channel	CM3
Pulse duration time	64 nsec
Symbol rate	0.9803 Mbps
Modulation	PPM
Center frequency Bandwidth	9th band (7.98 GHz) 500 MHz
Data bits length(/packet)	270 bits
CRC bits length	16 bits
RCPC codes	Parent code rate 1/2, Constraint length 3 Hard decision Viterbi
RS codes	GF(2^3), (7,3) GMD decoding
Limit of retransmission	1,2,3

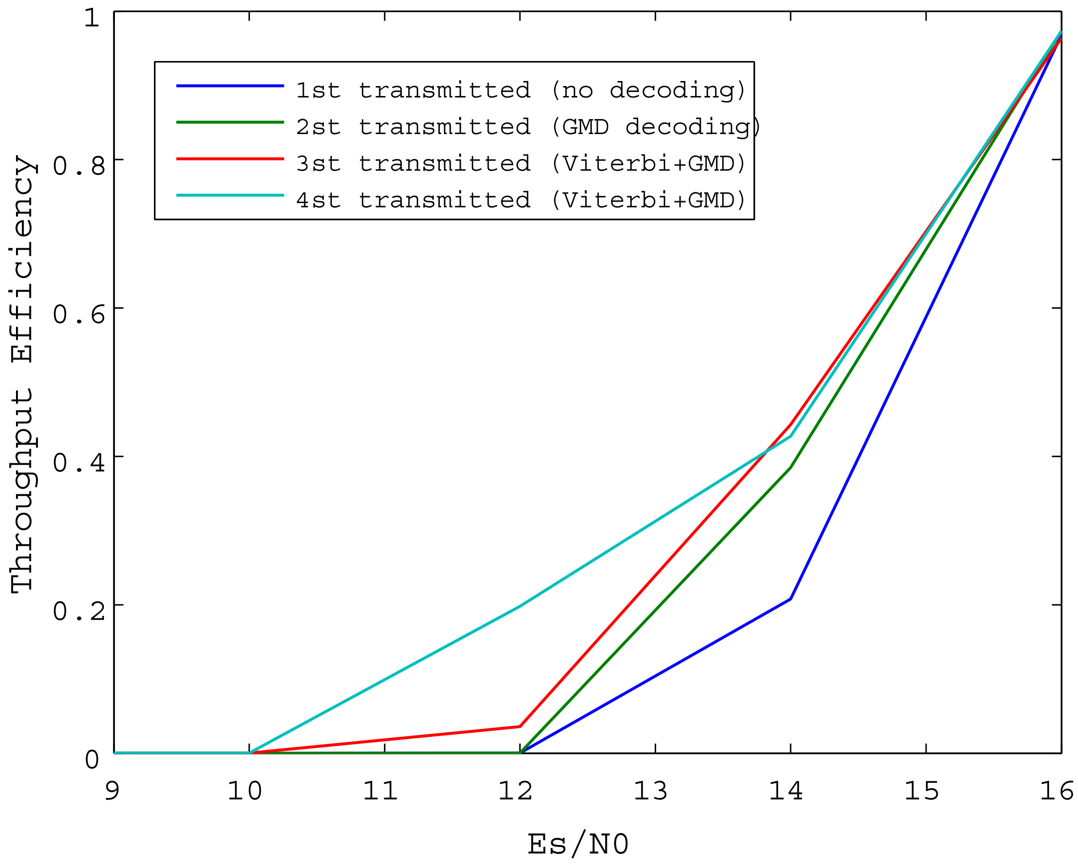
Numerical evaluation: CM3



Numerical evaluation: CM3

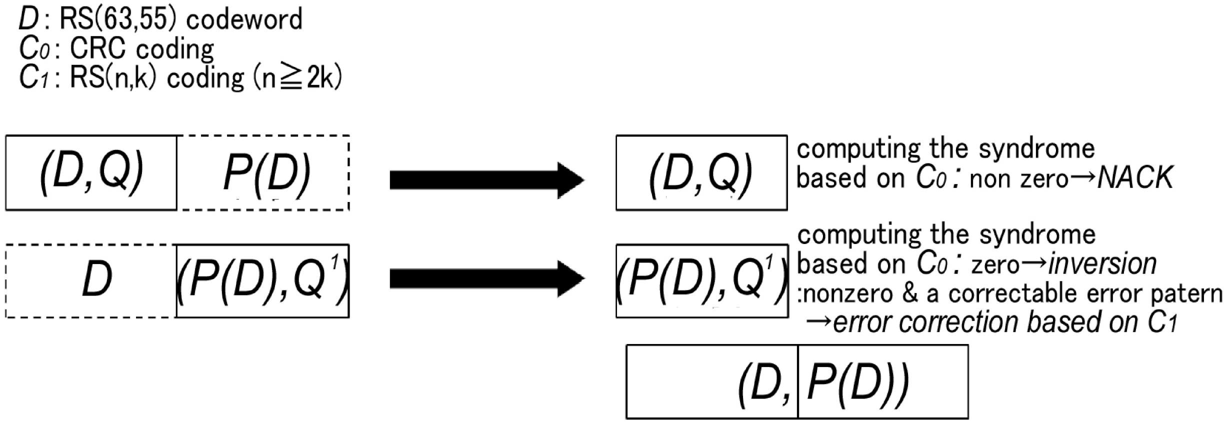


Numerical evaluation: CM3

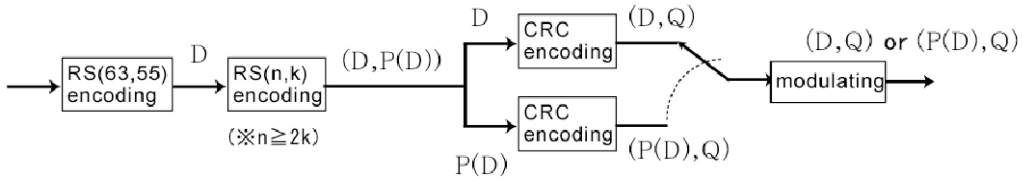


HARQ-Concatenated coding

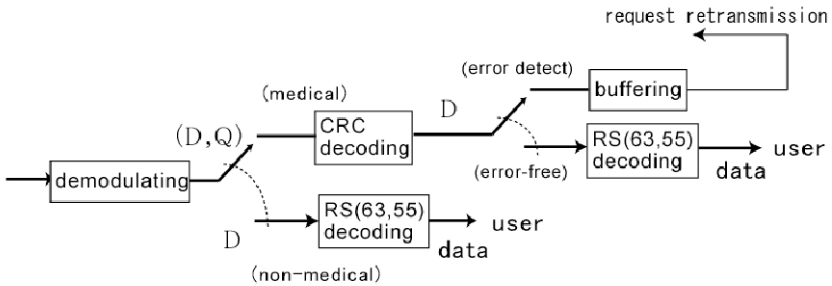
- Inner codes: systematic RS(63,55). Outer codes: RS(n,k) codes.



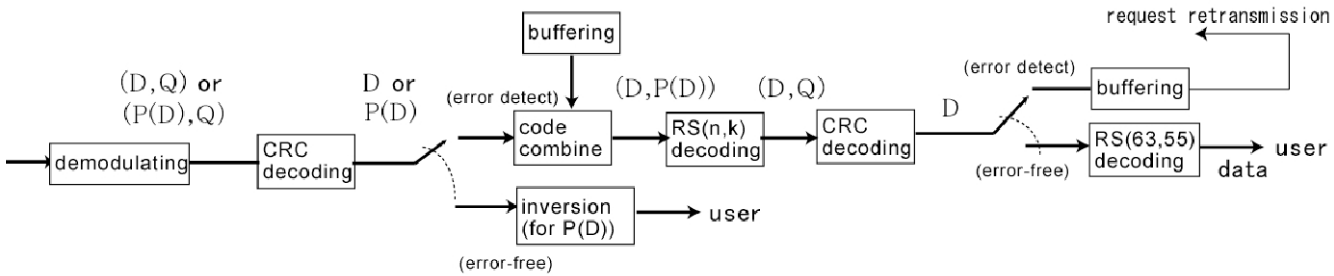
HARQ-Concatenated RS coding



(a) transmitter

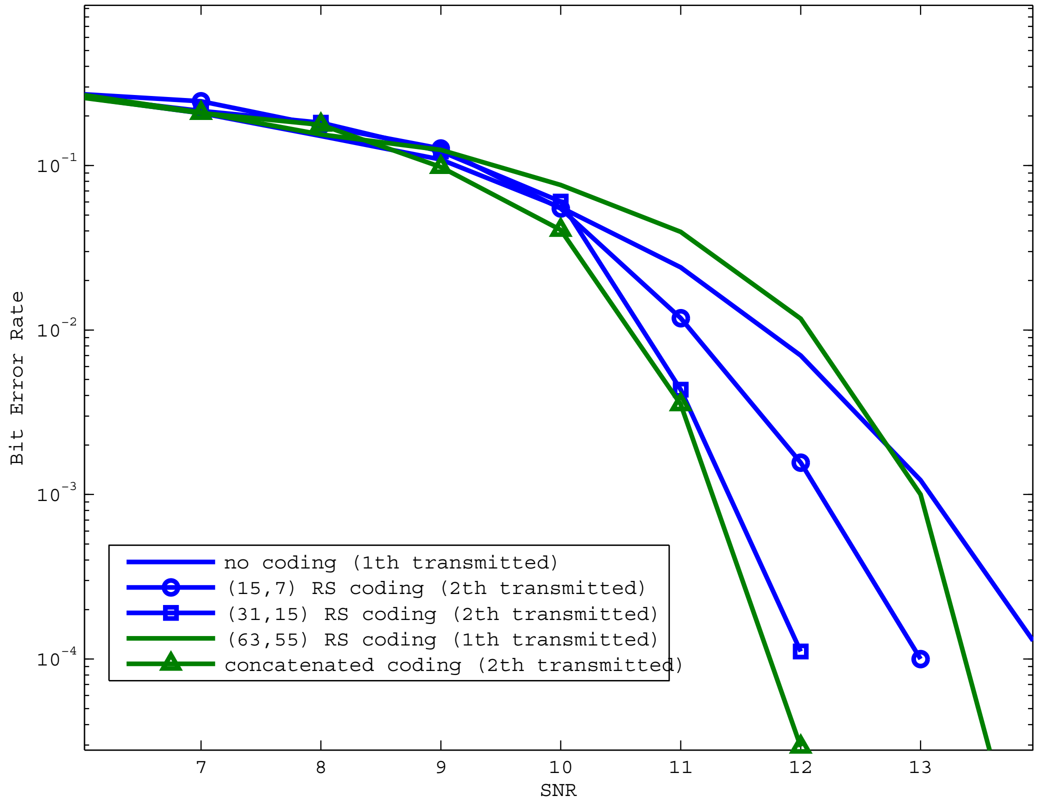


(b) receiver (receiving first transmission)

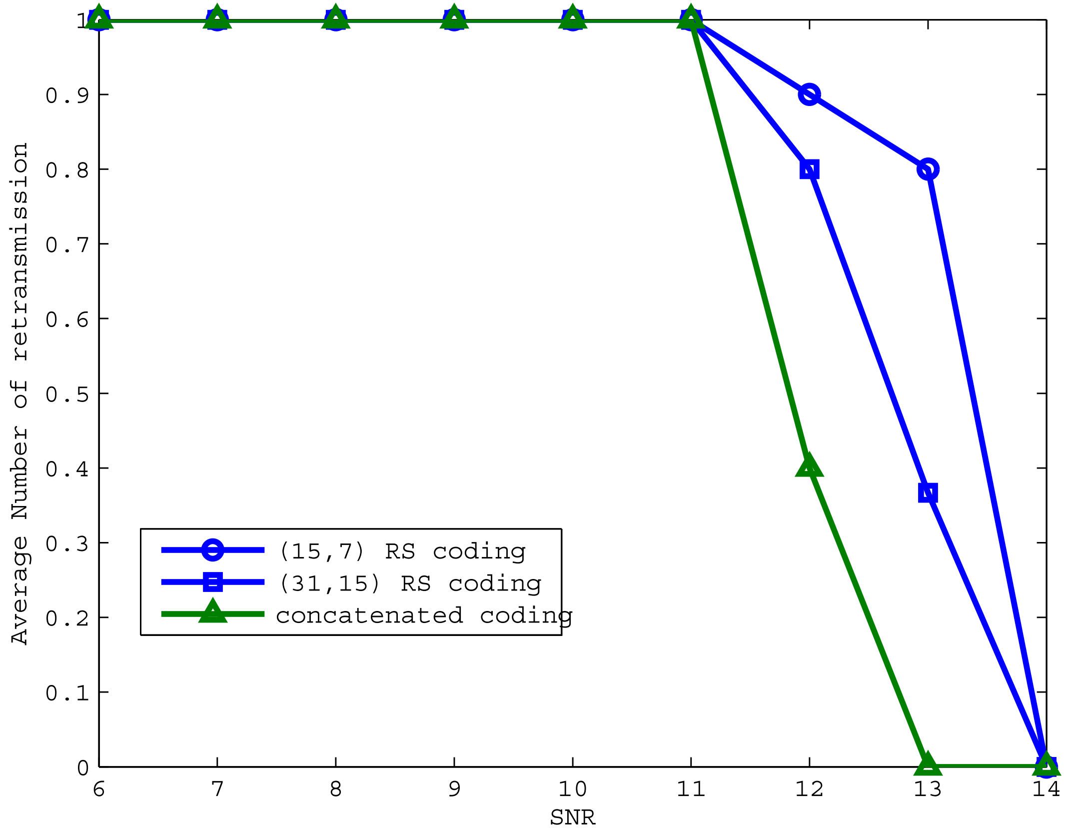


(c) receiver (receiving retransmission)

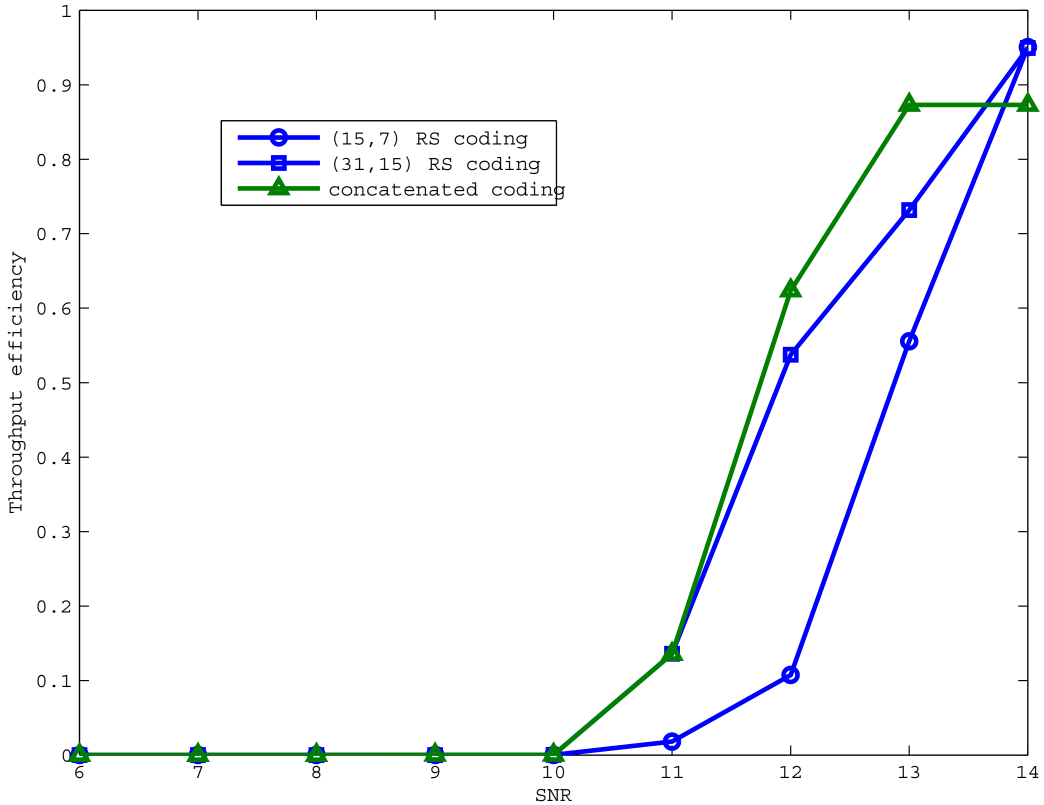
Numerical evaluation: CM3



Numerical evaluation: CM3



Numerical evaluation: CM3



Conclusions

We propose HARQ as an attractive adaptive error control mechanism for BANs in order to provide high QoS

- We propose QoS in terms of minimum average throughput and end-to-end delay.
- This will provide high reliability for critical medical (on non-medical) applications in harsh channel conditions.