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Error Models for Digital Channels and Applications to Wireless Communications Systems

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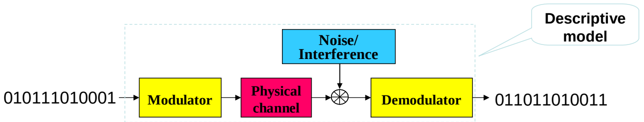
Introduction

- **Two types of wireless channels:**
  - **Physical channels:** real wireless communication environments; parameters of interest are signal strength, noise/interference power, etc.
  - **Digital channels:** include transmitters, receivers, and physical channels as long as the input and output are discrete-time; parameters of interest are number and distribution of error events, etc.
- **Error sequences are obtained by comparing the input and output sequences of digital channels. Errors encountered in digital wireless channels are not independent but often occur in bursts or clusters.**
- **Error models: channel models which describe the statistical properties of bursty error sequences encountered in digital wireless channels; crucial to the design and performance evaluation of high layer wireless communication protocols and error control schemes.**
  - **Descriptive models:** characterise the burst error statistics of target error sequences obtained directly from real digital channels.



  - **Generative models:** Identify a mechanism that generates error sequences having similar statistics to those of target error sequences.

- **The aim is to develop new generative models that are more accurate and simple comparing to well-known generative models and to study their burst error statistics.**

Burst Error Statistics

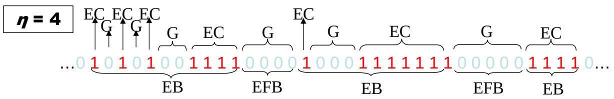
Some definitions:

Gap (G): a string of consecutive zeros between two ones, having a length equal to the number of zeros.

Error Cluster (EC): a string of consecutive ones, having a length equal to the number of ones.

Error-free burst (EFB): an all-zero bit sequence with a length of at least η bits, where η is a positive integer.

Error burst (EB): a sequence of ones and zeros beginning and ending with an error. They are separated from neighbouring EBs by EFBs.



Statistics:

$P(1^m|0)$: Error-cluster distribution, which is the probability that a correct bit is followed by at least m consecutive error bits.

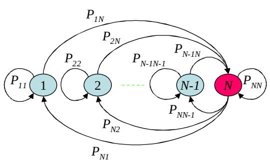
$P(m,n)$: Block error probability distribution, which is the probability that a block of n bits contain at least m errors.

$Q(l,n)$: Block burst probability distribution, which is the probability of an error burst of length l occurring in a block of length n. The length of a burst is the number of zeros and ones between the first error to the last error in the block.

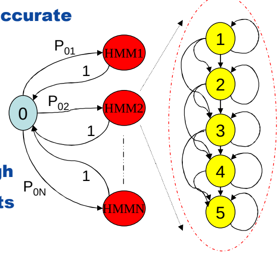
BECF: Bit error correlation function, which is the conditional probability that the Δkth bit following an error bit, is also in error.

Well-Known Generative Models

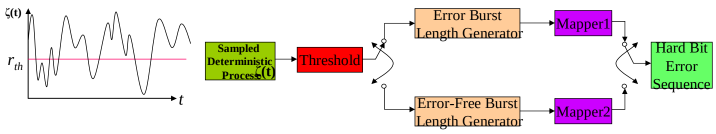
- **Simplified Fritchman's model (SFMs)**
  - ✓ Simple model
  - ✓ Non-renewal
  - ✓ Applied to many channels, e.g., HF and VHF
  - ✓ The error-free run distribution is in the form of sum of exponentials
  - × Their statistical properties are not very accurate
  - × Not applicable to slow fading channels



- **Hidden Markov Models (HMMs)**
  - ✓ Give more accurate results
  - × The number of states is normally very high
  - × Apply only to specific forms of error bursts

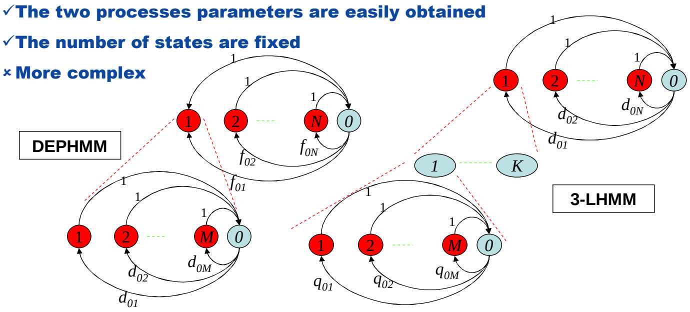


- **Deterministic Process Based Generative Models (DPBGMs)**
  - ✓ Applicable to both hard and soft error sequences
  - × Need the reference sequence to generate error sequences



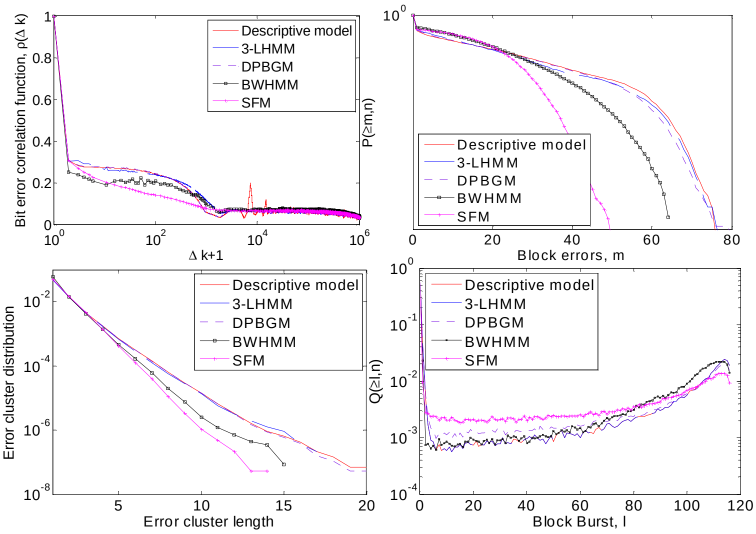
Main contributions

- **Double Embedded Processes Based HMMs (DEPHMMs)**
  - The first process classifies the error bursts according to the maximum gap. The second process represents the clusters and gaps of each error burst class
  - ✓ The two processes parameters are easily obtained
  - × High accuracy requires a complex system
- **Three Layered HMMs (3-LHMMs)**
  - The first layer classifies the error bursts according to the maximum cluster. The second layer classifies further each class in upper layer according to the maximum gap. Finally, The third layer represents the clusters and gaps of each error burst class
  - ✓ The two processes parameters are easily obtained
  - ✓ The number of states are fixed
  - × More complex



Simulations

Reference system: uncoded EGPRS tailored to TU-IFH channel, CIR= 8 dB, and η = 800.



Summary and Future Work

- **The new developed HMMS have simple parameterisation**
- **The DPBGMs have satisfactory results, but they do not create error bursts by themselves**
- **Future Works**
  - Developing soft generative models
  - Developing adaptive generative models

Publications

1. Omar S. Salih, Cheng-Xiang Wang, and Dave I. Laurenson, "Double embedded processes based hidden Markov models for binary digital wireless channels," *Proc. IEEE ISWCS'08*, Iceland, 21-24 Oct. 2008.

2. Omar S. Salih, Cheng-Xiang Wang, and Dave I. Laurenson, "Three-layered hidden Markov models for binary digital wireless channels," *Proc. IEEE ICC'09*, Dresden, Germany, 14-18 Jun. 2009.