# The Wide Trail Design Strategy

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**Abstract.** We explain the theoretical background of the wide trail design strategy, which was used to design Rijndael, the Advanced Encryption Standard (AES). In order to facilitate the discussion, we introduce our own notation to describe differential and linear cryptanalysis. We present a block cipher structure and prove bounds on the resistance against differential and linear cryptanalysis.

## 1 Introduction

The development of differential [2] and linear cryptanalysis [7] has led to several design theories for block ciphers. The most important requirement for a new cipher is that it resists state-of-the-art cryptanalytic attacks. Preferably, this can be demonstrated in a rigorous, mathematical way. The second requirement is a good performance and an acceptable 'cost', in terms of CPU requirements, memory requirements, . . .

The Wide trail strategy is an approach to design the round transformations of block ciphers that combine efficiency and resistance against differential and linear cryptanalysis. The strategy has been used in the design of Rijndael, the block cipher which has been selected to become the Advanced Encryption Standard (AES). In this article we describe the application of the strategy to the design of a certain type of block ciphers only, but the strategy can easily be extended to more general block cipher structures. Moreover, the wide trail strategy can also be applied to the design of synchronous stream ciphers and hash functions.

In order to explain the wide trail strategy, we introduce our own notation for differential and linear cryptanalysis. We are convinced that a good notation helps to understand the reasonings, and our notation is suited very well to understand the wide trail strategy. We introduce a general block cipher model and explain how linear correlations and difference propagation probabilities are built up in block ciphers designed according to this model. Subsequently, we explain the basic principles of the wide trail strategy and introduce our new diffusion measure, the *branch number*. We explain its relevance in providing bounds for the probability of differential trails and the correlation of linear trails over two rounds. We then introduce a cipher structure that combines efficiency with high resistance against linear and differential cryptanalysis. The resistance against linear and differential cryptanalysis is based on a theorem that lower bounds the

# Design Of Rijndael The Wide Trail Strategy Explained

**Joan Daemen,Vincent Rijmen**

**Design Of Rijndael The Wide Trail Strategy Explained:**

*The Design of Rijndael* Joan Daemen,Vincent Rijmen,2013-03-09 Rijndael was the surprise winner of the contest for the new Advanced En cryption Standard AES for the United States This contest was organized and run by the National Institute for Standards and Technology NIST be ginning in January 1997 Rijndael was announced as the winner in October 2000 It was the surprise winner because many observers and even some participants expressed scepticism that the D S government would adopt as an encryption standard any algorithm that was not designed by D S citizens Yet NIST ran an open international selection process that should serve as model for other standards organizations For example NIST held their 1999 AES meeting in Rome Italy The five finalist algorithms were designed by teams from all over the world In the end the elegance efficiency security and principled design of Rijndael won the day for its two Belgian designers Joan Daemen and Vincent Rijmen over the competing finalist designs from RSA IBM Counterpane Systems and an EnglishjIsraelijDanish team This book is the story of the design of Rijndael as told by the designers themselves It outlines the foundations of Rijndael in relation to the previous ciphers the authors have designed It explains the mathematics needed to and the operation of Rijndael and it provides reference C code and underst test vectors for the cipher      Cryptography and Coding Bahram Honary,2001-12-10 This book constitutes the refereed proceedings of the 8th International IMA Conference on Cryptography and Coding held in Cirencester UK in December 2001 The 33 revised full papers presented together with four invited papers were carefully reviewed and selected from numerous submissions Among the topics covered are mathematical bounds statistical decoding schemes for error correcting codes multifunctional and multiple access communication systems low density parity check codes iterative coding authentication key recovery attacks stream cipher design analysis of ECIES algorithms and lattice bases attacks on IP based protocols      **Progress in Cryptology - INDOCRYPT 2002** Alfred Menezes,Palash Sarkar,2003-07-01 The third successful completion of the INDOCRYPT conference series marks the acceptance of the series by the international research community as a forum for presenting high quality research It also marks the coming of age of cryptology research in India The authors for the submitted papers were spread across 21 countries and 4 continents which goes a long way to demonstrate the international interest and visibility of INDOCRYPT In the previous two conferences the submissions from India originated from only two institutes this increased to six for the 2002 conference Thus INDOCRYPT is well set on the path to achieving two main ob jectives to provide an international platform for presenting high quality research and to stimulate cryptology research in India The opportunity to serve as a program co chair for the third INDOCRYPT carries a special satisfaction for the second editor Way back in 1998 the sci ti c analysis group of DRDO organized a National Seminar on Cryptology and abbreviated it as NSCR On attending the seminar the second editor suggested that the conference name be changed to INDOCRYPT It is nice to see that this suggestion was taken up giving us the annual INDOCRYPT conference ries Of course the form character and execution of the conference series

was the combined e ort of the entire Indian cryptographic community under the dynamic leadership of Bimal Roy

**Advances in Cryptology - EUROCRYPT 2002** Lars Knudsen,2002-04-17 This book constitutes the refereed proceedings of the International Conference on the Theory and Application of Cryptographic Techniques EUROCRYPT 2002 held in Amsterdam The Netherlands in April May 2002 The 33 revised full papers presented were carefully reviewed and selected from a total of 122 submissions The papers are organized in topical sections on cryptanalysis public key encryption information theory and new models implementational analysis stream ciphers digital signatures key exchange modes of operation traitor tracing and id based encryption multiparty and multicast and symmetric cryptology **Progress in Cryptology** ,2002 **VLSI Circuits and Systems** ,2005 **Hiding Data - Selected Topics** Rudolf Ahlswede,2016-04-18 Devoted to information security this volume begins with a short course on cryptography mainly based on lectures given by Rudolf Ahlswede at the University of Bielefeld in the mid 1990s It was the second of his cycle of lectures on information theory which opened with an introductory course on basic coding theorems as covered in Volume 1 of this series In this third volume Shannon s historical work on secrecy systems is detailed followed by an introduction to an information theoretic model of wiretap channels and such important concepts as homophonic coding and authentication Once the theoretical arguments have been presented comprehensive technical details of AES are given Furthermore a short introduction to the history of public key cryptology RSA and El Gamal cryptosystems is provided followed by a look at the basic theory of elliptic curves and algorithms for efficient addition in elliptic curves Lastly the important topic of oblivious transfer is discussed which is strongly connected to the privacy problem in communication Today the importance of this problem is rapidly increasing and further research and practical realizations are greatly anticipated This is the third of several volumes serving as the collected documentation of Rudolf Ahlswede s lectures on information theory Each volume includes comments from an invited well known expert In the supplement to the present volume R diger Reischuk contributes his insights Classical information processing concerns the main tasks of gaining knowledge and the storage transmission and hiding of data The first task is the prime goal of Statistics For transmission and hiding data Shannon developed an impressive mathematical theory called Information Theory which he based on probabilistic models The theory largely involves the concept of codes with small error probabilities in spite of noise in the transmission which is modeled by channels The lectures presented in this work are suitable for graduate students in Mathematics and also for those working in Theoretical Computer Science Physics and Electrical Engineering with a background in basic Mathematics The lectures can be used as the basis for courses or to supplement courses in many ways Ph D students will also find research problems often with conjectures that offer potential subjects for a thesis More advanced researchers may find questions which form the basis of entire research programs **Cryptography and Network Security** William Stallings,2006 In this age of viruses and hackers of electronic eavesdropping and electronic fraud security is paramount This solid up to date tutorial is a comprehensive treatment of

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