Advanced Tools from Modern Cryptography

Lecture 0

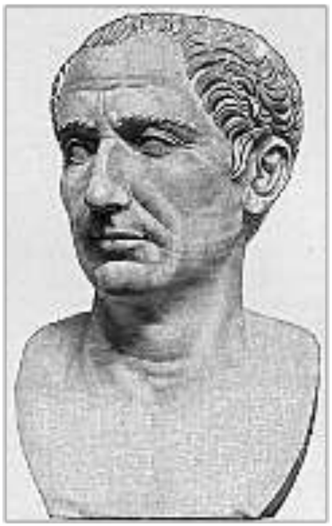
Manoj Prabhakaran

IIT Bombay

"Old" Cryptography

Scytale (ancient Greece)

Caesar Cipher



100 BC - 44 BC

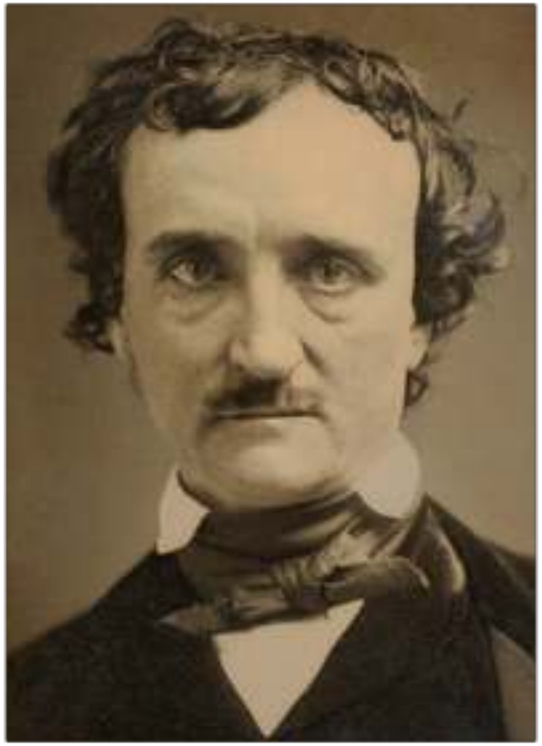
801-873

Cryptanalysis (simple frequency analysis)
of Caesar cipher by Al-Kindi

“Old” Cryptography

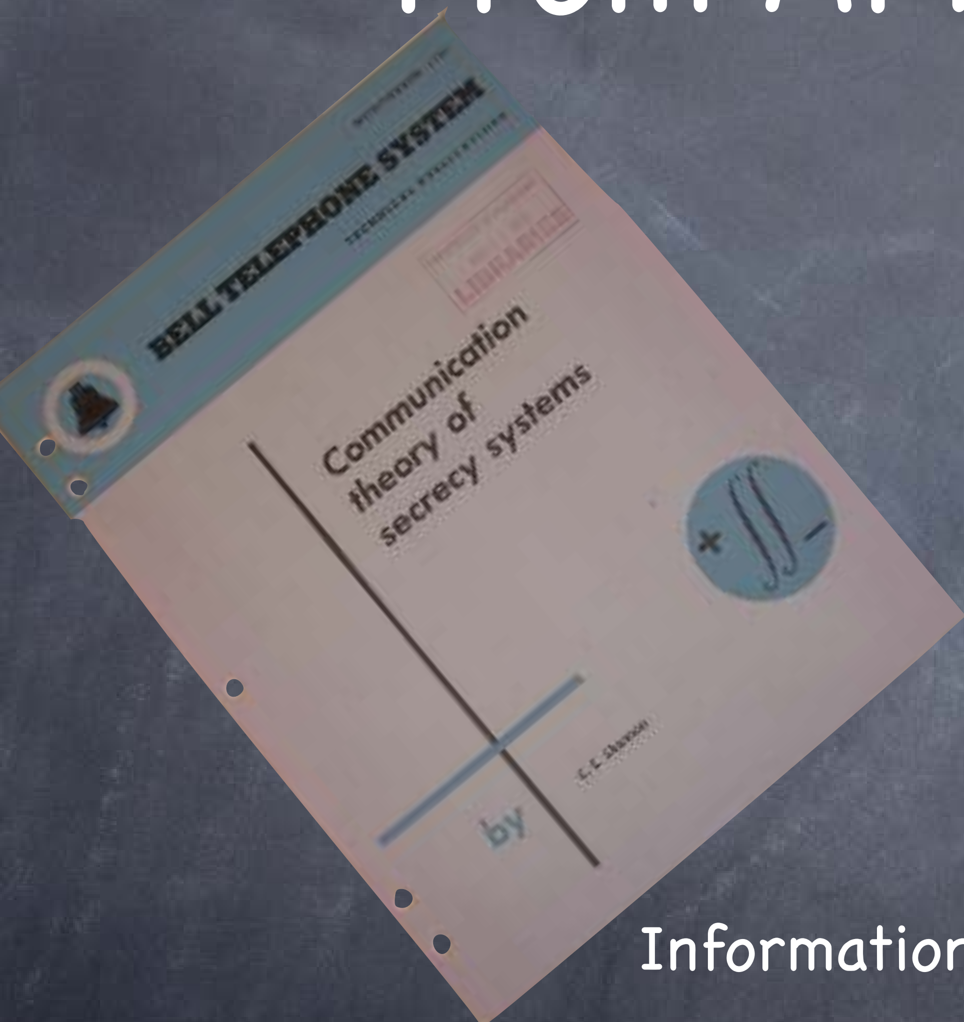
“Human ingenuity cannot concoct a cypher which human ingenuity cannot resolve”

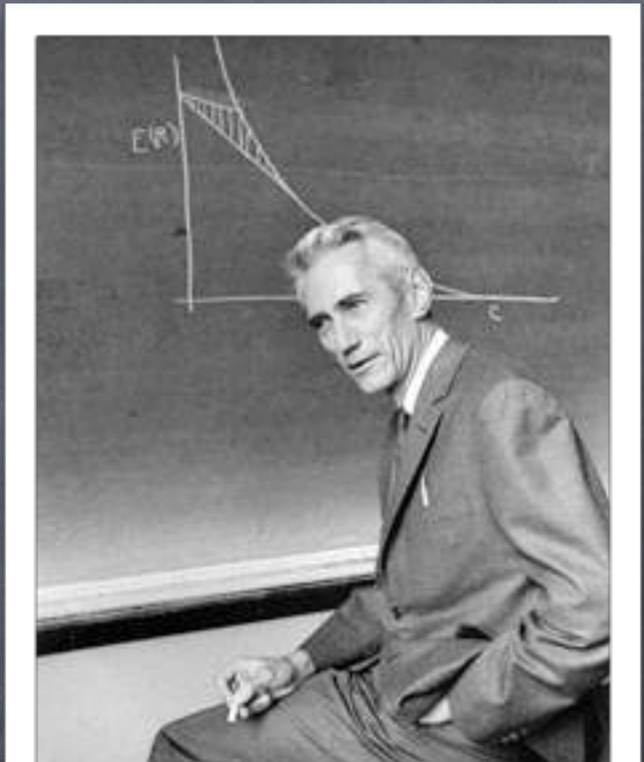
-Edgar Allan Poe



1809-1849

From Art to Science





1916 - 2001

Information can be quantified

Perfect secrecy: ciphertext has zero information about the message

Key to perfect secrecy: Randomness

Modern Cryptography

- What's different?
  - "Provable Security"
    - Definitions of security
    - (Possible) reliance on computational hardness
  - Beyond (symmetric-key) encryption
    - Started with Public-Key Encryption and Digital Signatures (which are very practical today)
    - Shortly followed by **more complex concepts like Secure Multi-Party Computation** (which are not yet widely known/used)

Modern Cryptography

- Some tools
  - **Secure Multi-Party Computation** (MPC)
    - In particular, **Zero-Knowledge Proofs**
  - **Private Information Retrieval** (PIR)
  - **Fully Homomorphic Encryption** (FHE)
  - **Functional Encryption** (FE)
  - **Obfuscation**
  - **Searchable Encryption**
  - **Oblivious RAM** (ORAM)
  - **Leakage-Resilient tools**
- Tools for what?

Collaboration

- … Among mutually distrusting entities
- **Secure Multi-Party Computation**
  - Example: Company A is shopping for parts for its new product from a supplier, Company B.
  - Example: Auctions, where only the winners' payments need to be revealed
  - Example: Govt. agencies collaborating to enforce laws while respecting the privacy of citizens

Securing Cloud Storage

- **Private Information Retrieval**
  - Don't want the server to see my access pattern
- **Searchable Encryption**
  - Allow search operations on data stored encrypted on the server (OK to reveal the access pattern)
- **Oblivious RAM**
  - Allow complex operations on data stored on the server, and do not reveal access pattern

Computing on Encrypted Data

- Similar goals as achieved by MPC, but with very restricted interaction among parties (and weaker security guarantees)
- **Fully Homomorphic Encryption**: computing server does not see the data; client need not do the computation, but only encryption/decryption
- **Functional Encryption**: keys can be issued to allow computation of specific functions, with the outcome becoming available to the computing party
- **Obfuscation**: "Encrypted" function that can be run on any input (without needing a key)

Connections

- These are also often tools for building other cryptographic tools
  - e.g., ORAM can be used for MPC
  - e.g., MPC can be used for FE
  - e.g., MPC for leakage resilience
- They share some common underlying primitives
  - e.g., Secret-sharing, Randomized Encoding

Definitions

- Important to be precise about what these (complicated) tools actually guarantee
- Even for a simple tool like encryption, easy to misunderstand its guarantees
    - e.g., malleability, circular (in)security, ...
- Strong security definitions are often provably impossible to achieve for many of these tools
    - e.g., (standard) "universally composable" security for MPC, "virtual black box" security for obfuscation, etc.

Course Plan

- Quick run-through of basic concepts like indistinguishability and basic tools like pseudorandom functions
- Will start with MPC
- As many other topics as possible, as time permits

Course Logistics

- Grading:
  - Two Quizzes (60%)
  - ≈3 HW assignments (18%)
  - Course project (20%)
  - Attendance (2%)
- "Theory" course: no programming requirement, but your course project could be a programming project
  - We have an MPC programming language now!
- Office hours TBA
- Course webpage: see cse.iitb.ac.in/~mp/teach/