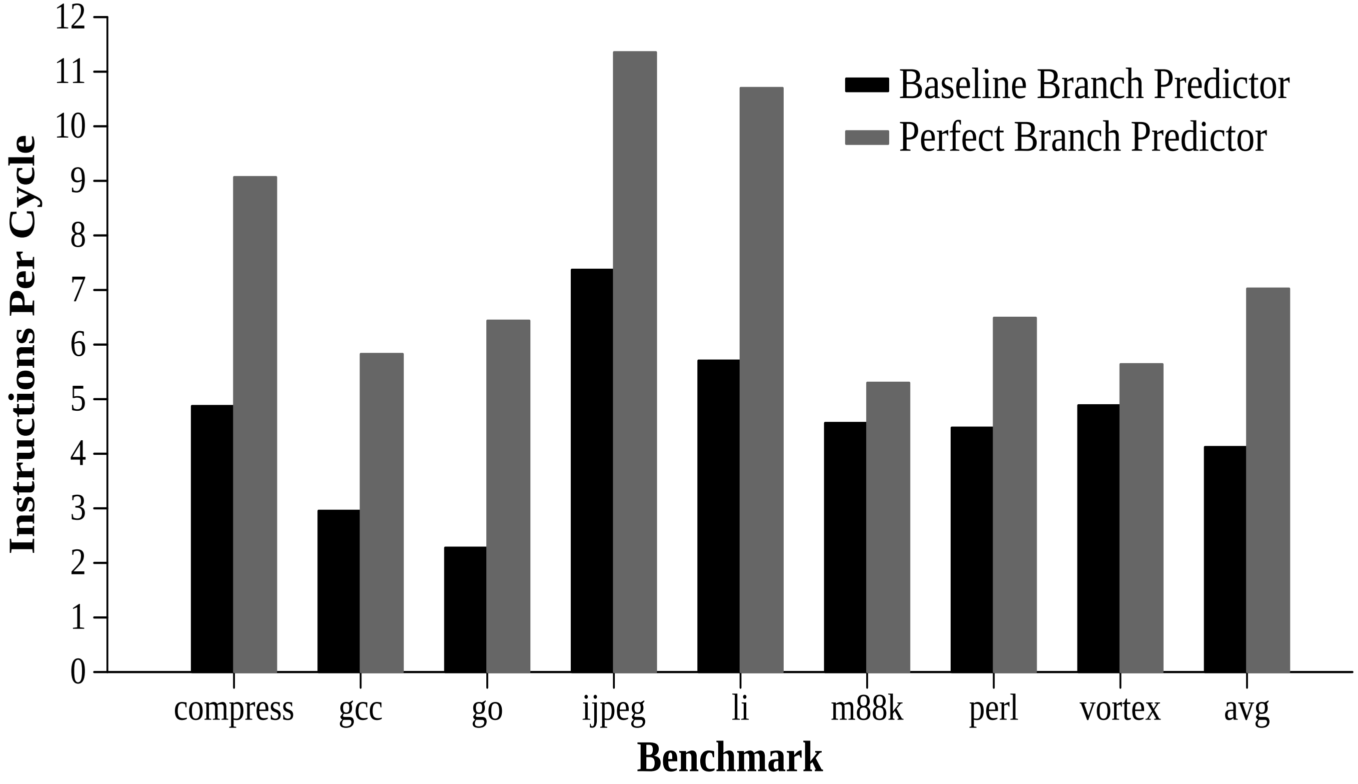
# Configurations for Two Machines

- Both Machines:
  - 16 Wide (Fetch, Execute, and Retire)
  - 64 Kbyte I & D Caches
- First Machine: Real Branch Prediction
  - Conditional: 16 Kbyte Gshare
  - Indirect: 2 Kbyte Pattern-Based
- Second Machine: Perfect Branch Prediction

# Are Branches a Problem?



# Variable Length Path Branch Prediction

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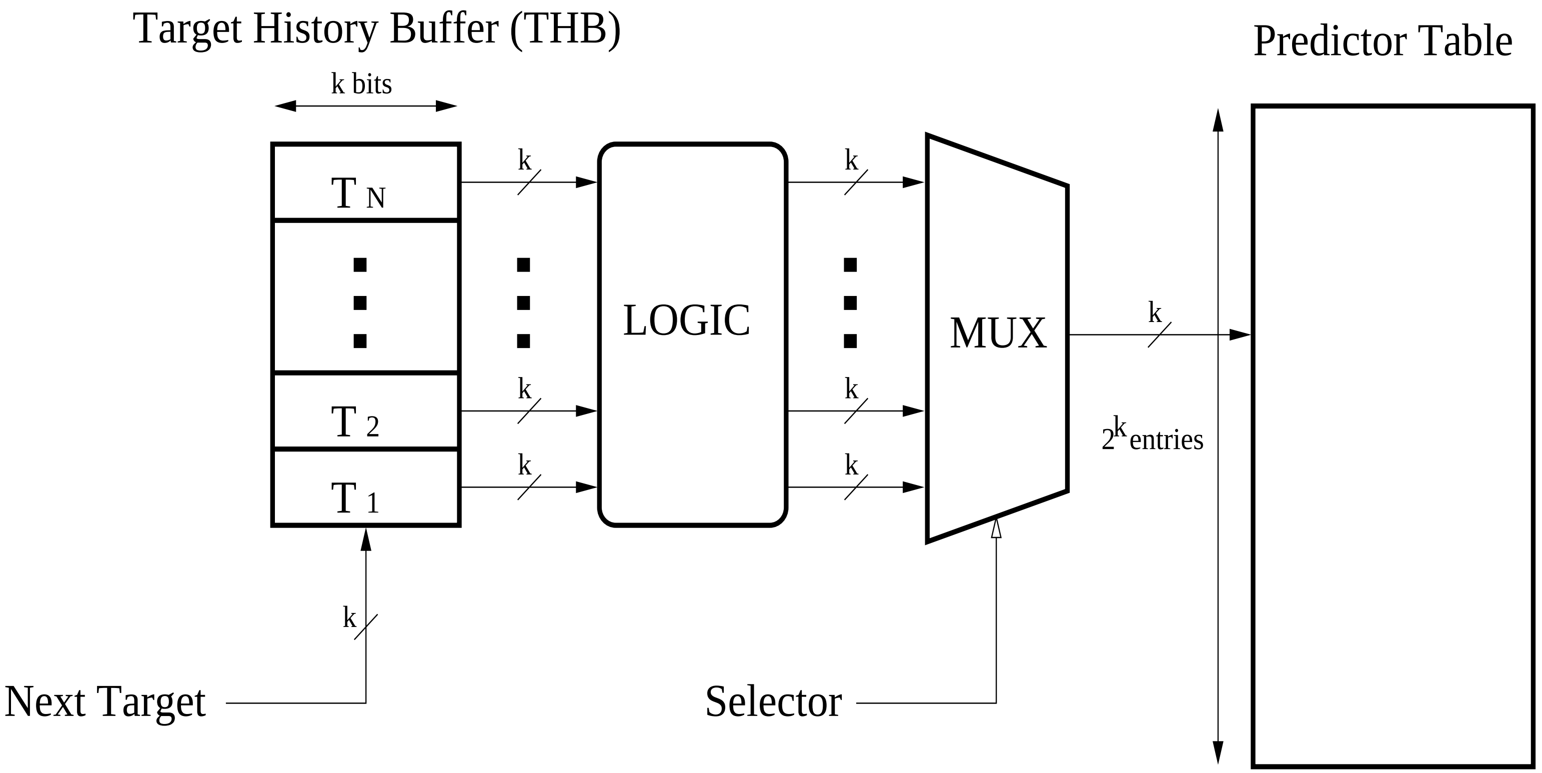
# Outline

- The Prediction Algorithm
- Implementation Considerations
- Experiments
- Conclusions

# Algorithm Overview

- Conditional and Indirect Branches
- Two Levels of History
  - 1st Level: Where are we? How did we get here?
  - 2nd Level: What happened the last time we were here?

# Structure of a Variable Length Path Predictor



# What does the Logic do?

Generates N Indices using N Hash Functions:

$$I_1 = HF_1(T_1),$$

$$I_2 = HF_2(T_1, T_2),$$

...

$$I_N = HF_N(T_1, T_2, \ldots, T_N)$$

# The Hash Functions

- Bad Idea:

$$HF_X(PATH_X) = T_1 \textbf{ xor } T_2 \ldots \textbf{xor } T_X$$

- Better Idea:

$$HF_X(PATH_X) = \mathsf{ROTATE}(T_1, 0) \textbf{ xor } \mathsf{ROTATE}(T_2, 1)$$
$$\ldots \textbf{xor } \mathsf{ROTATE}(T_X, X-1)$$

# Implementation Considerations

- Communicating the Hash Function to the Hardware
- Pipelining the Predictor

# Communicating the Hash Function Number (HFN) to the Hardware

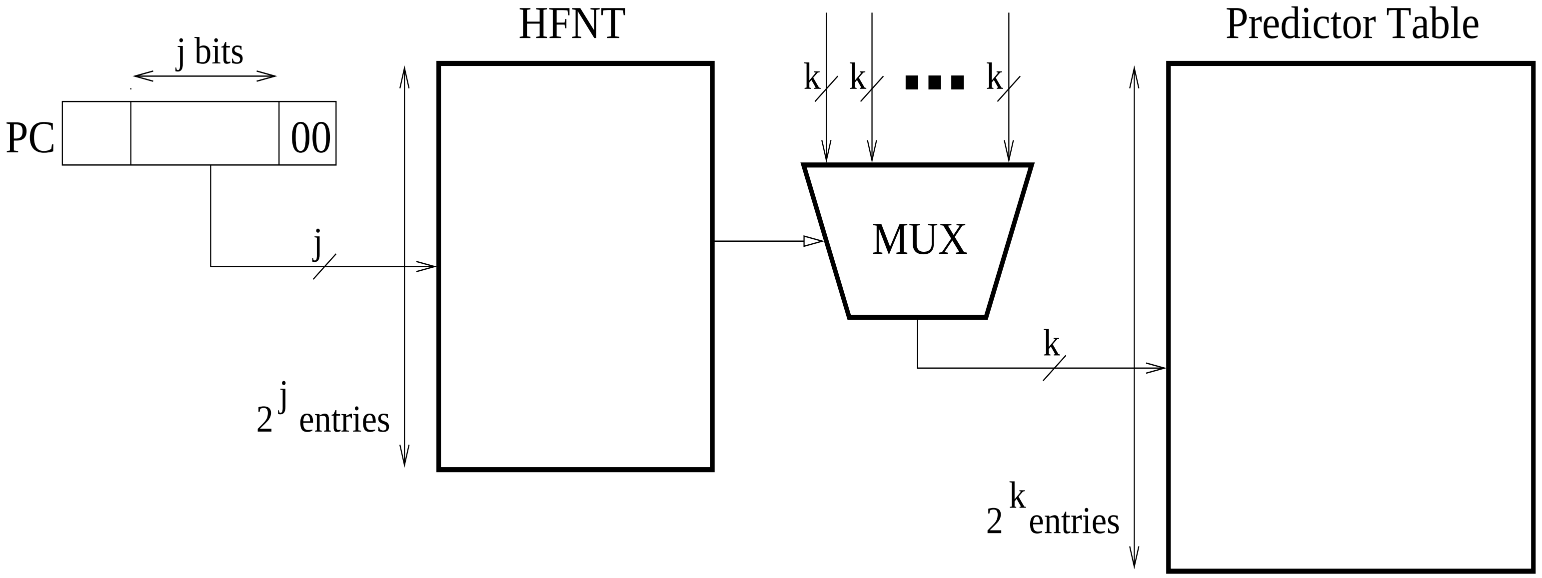
- Compiler Selects the HFN using Profiling Info

- HFN Communicated to Hardware via ISA
  - HFN Encoded in Opcode
  - HFN Encoded in Prefix Instruction

## Pipelining the Predictor

- Two Sequential Table Accesses
  - Hash Function Number Table
  - Predictor Table

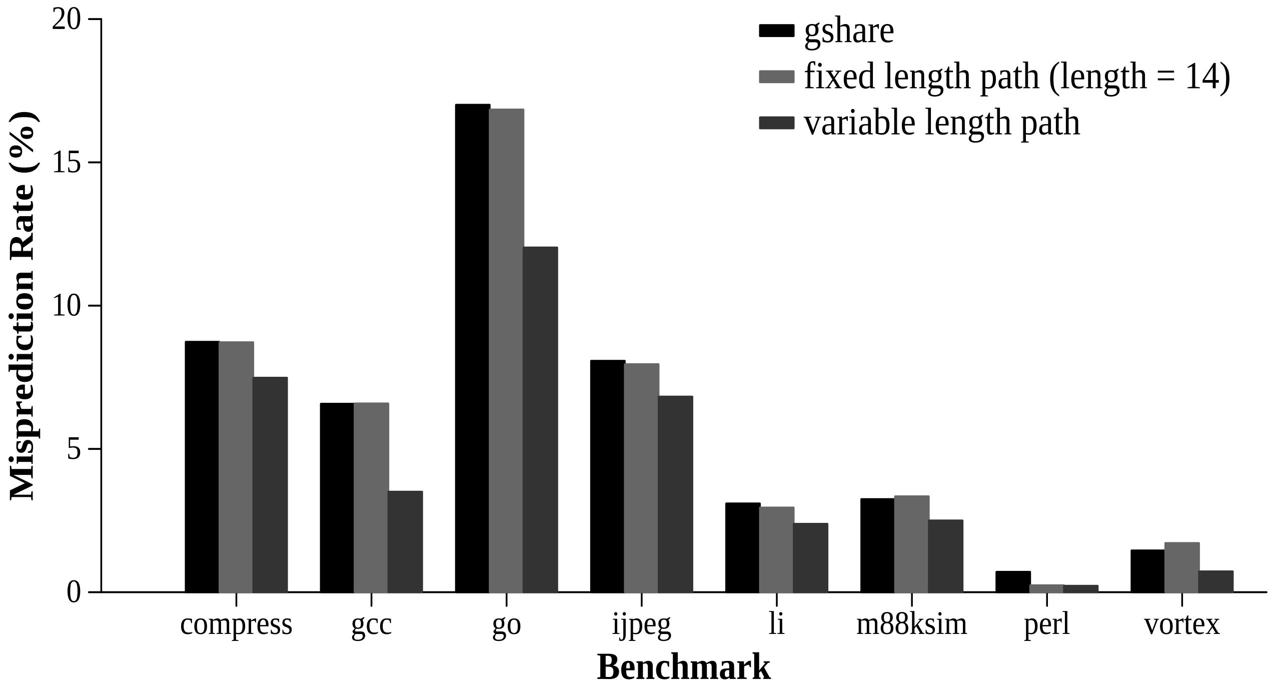
# Table Accesses Required to Make a Prediction



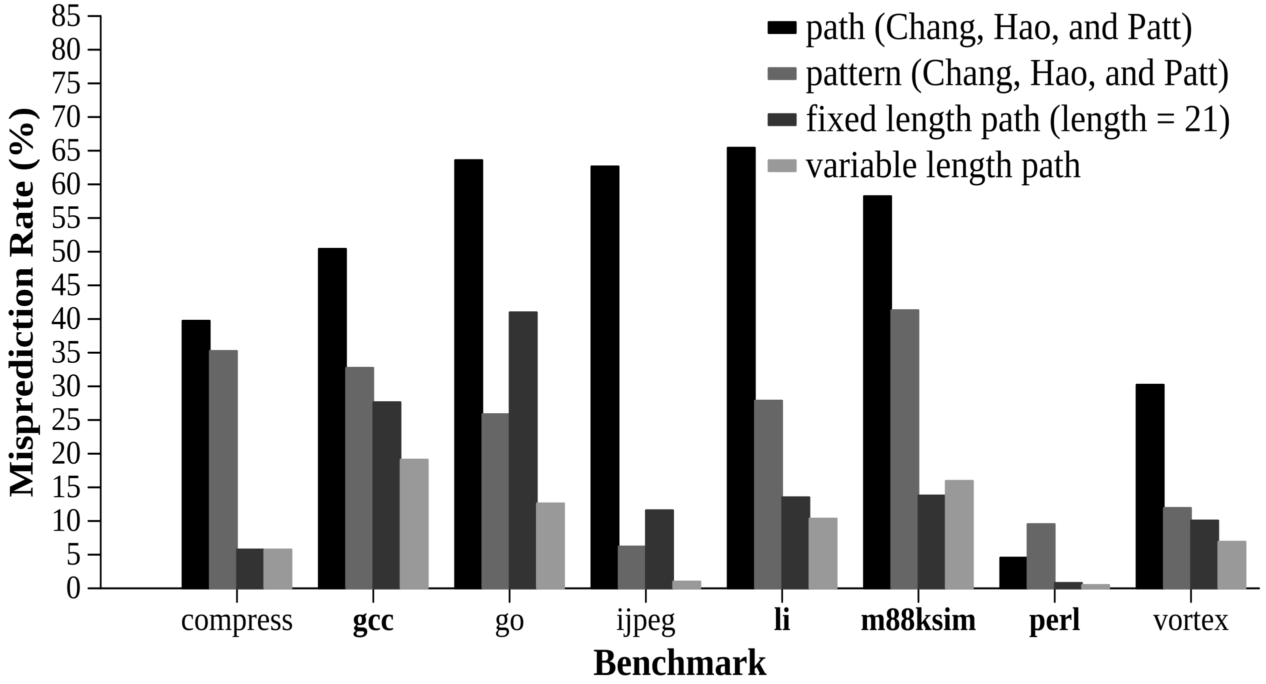
# Experiments

- Benchmarks: SPECint95 + Non-SPEC
- Executables Instrumented with Compaq/DIGITAL ATOM
- VLP Branch Predictor w/ 32 Hash Functions

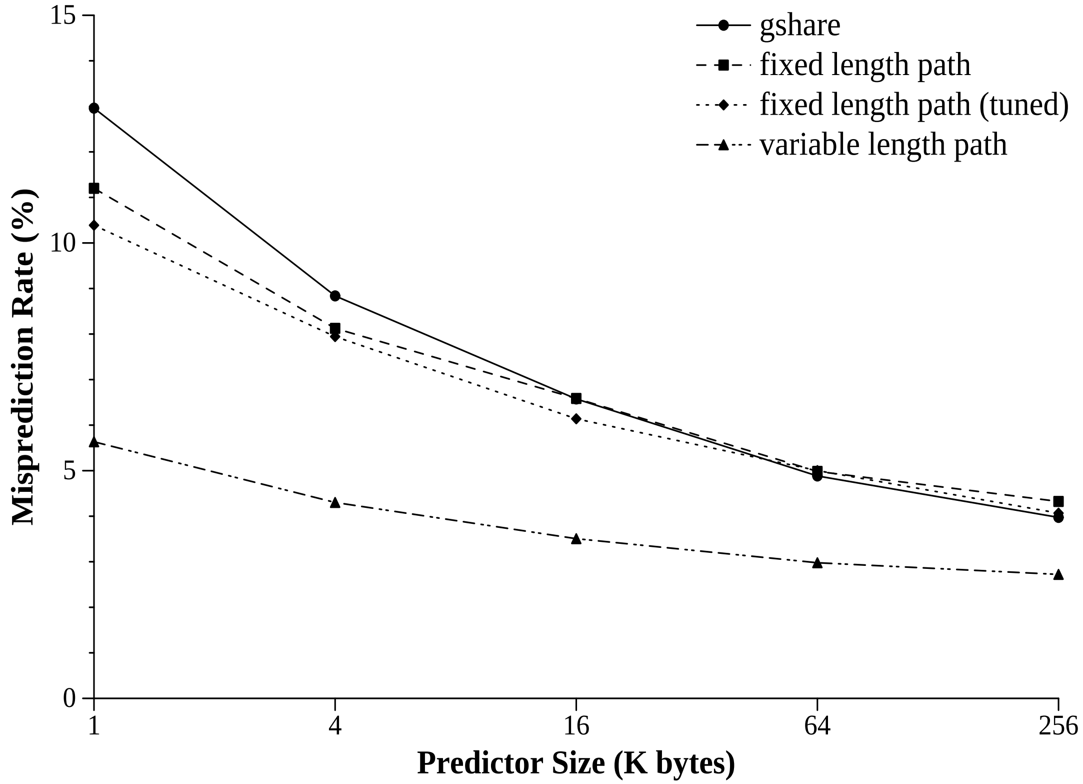
# Misprediction Rates for Cond. Branches with a 16K byte Predictor



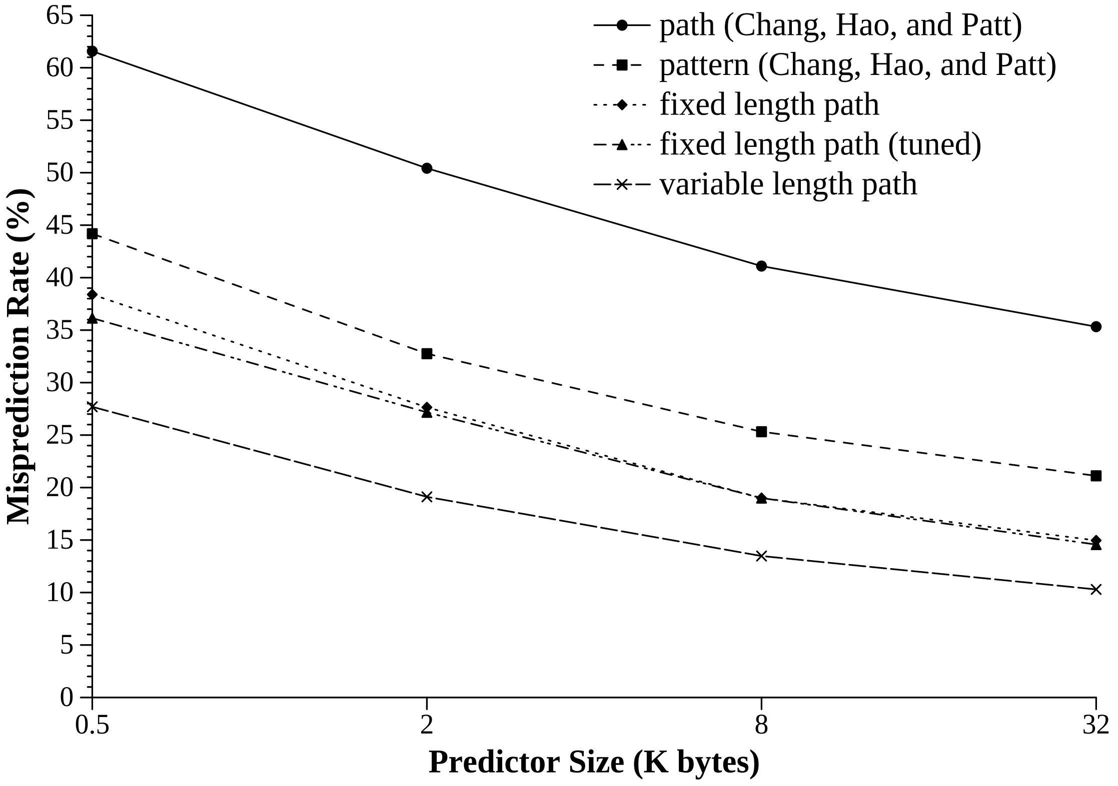
# Misprediction Rates for Ind. Branches with a 2K byte Predictor



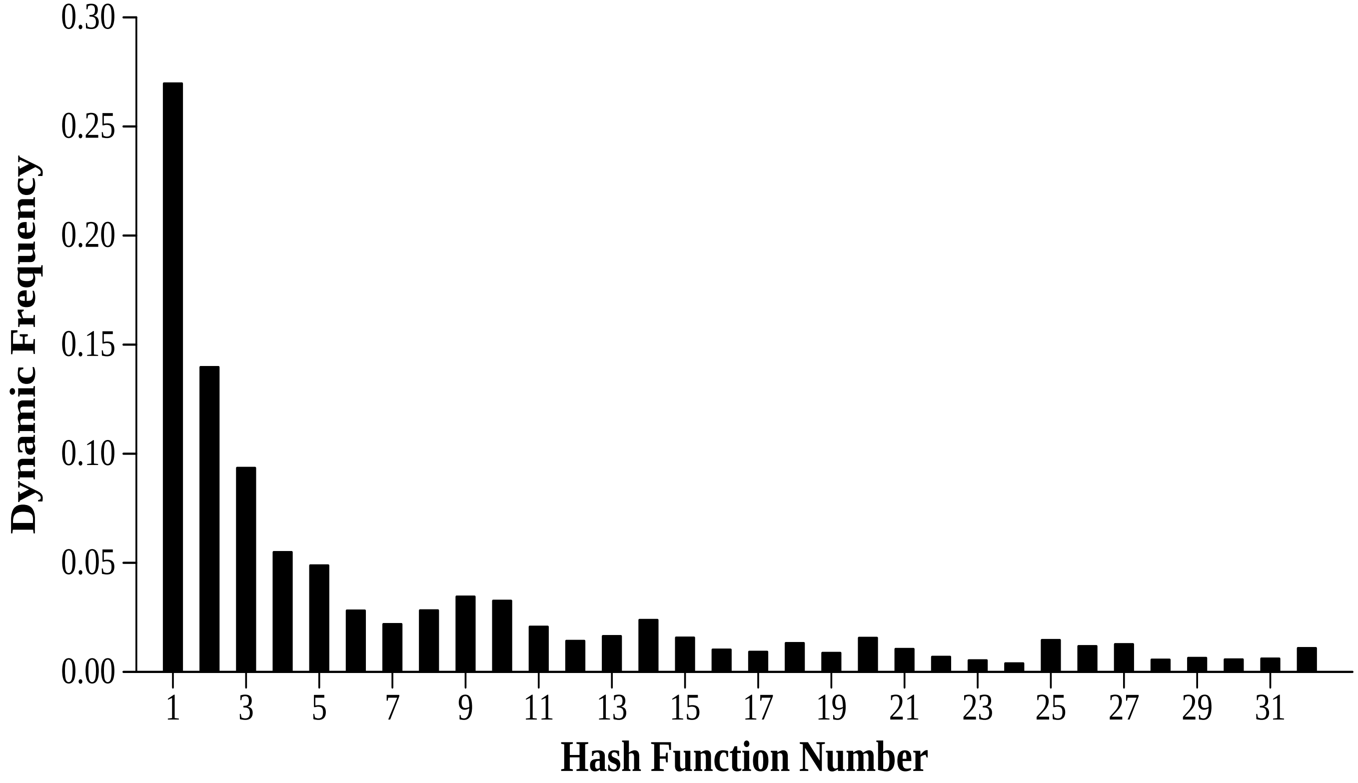
# Misprediction Rates for Cond. Branches in Gcc



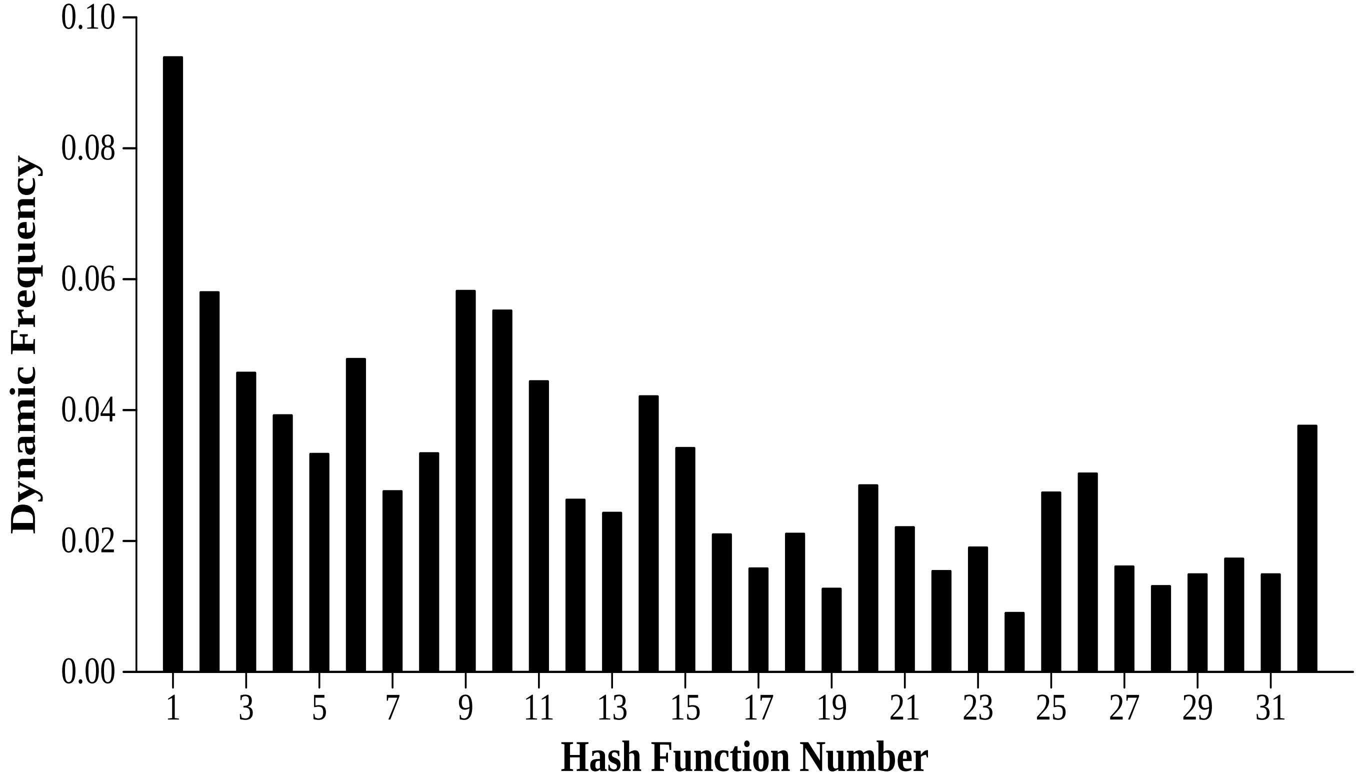
# Misprediction Rates for Ind. Branches in Gcc



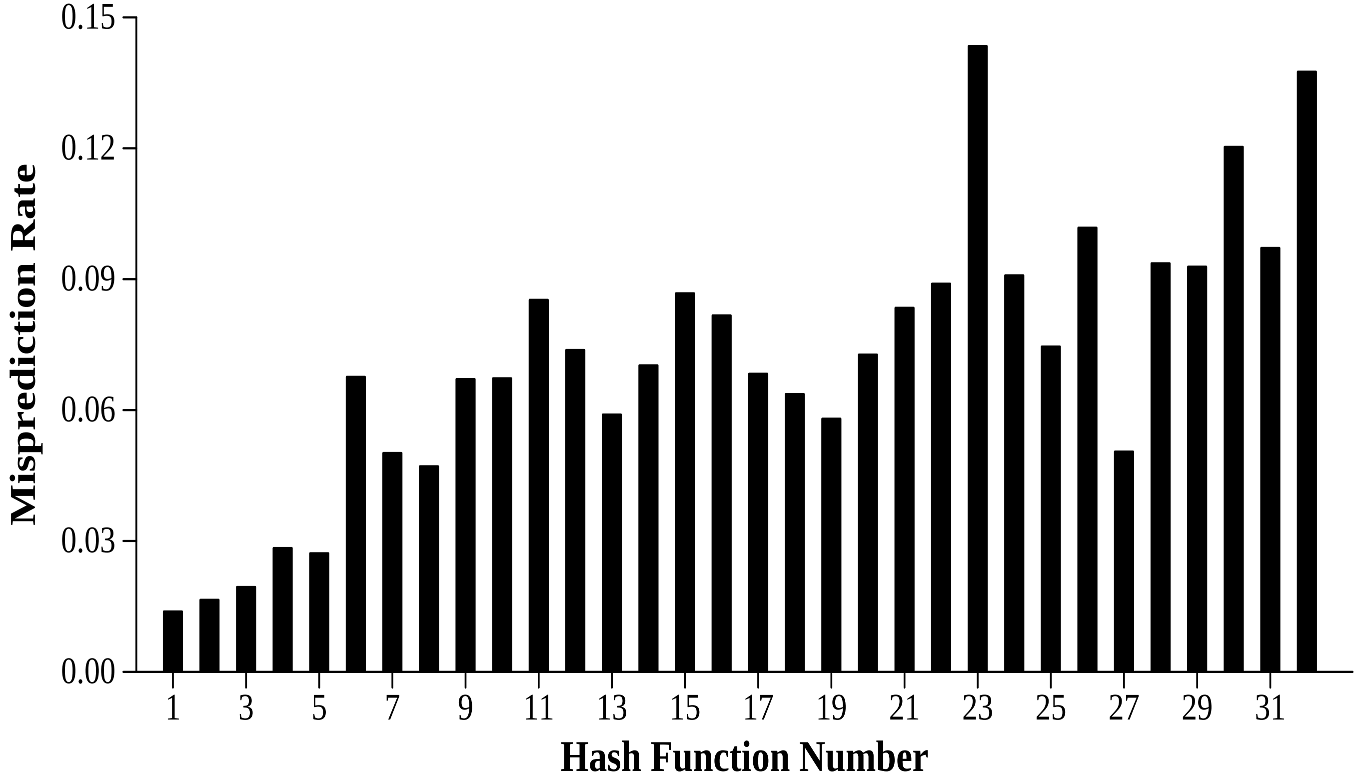
# Branches Per HFN (Gcc)



# Mispredictions Per HFN (Gcc)



# Misprediction Rates Per HFN (Gcc)



# Conclusions: Are Branches Still a Problem?