CS61C – 11/29/16

* Six Great Ideas in Computer Architecture
  + Design for Moore’s Law (Multicore, Parallelism, OpenMP, Project 4)
  + Abstraction to Simplify Design (Everything a number, Machine/Assembler Language, C, Project 2, Logic Gates, Datapaths, Project 3)
  + Make the Common Case Fast (RISC Architecture, Instruction Pipelining, Project 3)
  + Memory Hierarchy (Locality, Consistency, False Sharing, Project 4)
  + Performance via Parallelism/Pipelining/Prediction (the five kinds of parallelism, Project #3, #4, #5)
  + Dependability by Redundancy
* Dependability
  + Fault: failure of a component
    - May or may not lead to system failure
  + Spatial Redundancy: replicated data or check information or hardware to handle hard and soft (transient) failures
  + Temporal Redundancy: redundancy in time (retry) to handle soft (transient) failures
  + Dependability Measures:
    - Reliability: Mean Time To Failure (MTTF)
      * What is your expected run time to get to a state of likely failure?
    - Service interruption: Mean Time To Repair (MTTR)
    - Mean time between failure (MTBF)
      * MTBF = MTTF + MTTR
    - Availability = MTTF / (MTBF) = MTTF / (MTTF + MTTR)
    - Improving availability
      * Increase MTTF: More reliable hardware/software + Fault Tolerance
      * Reduce MTTR: improved tools and processes for diagnosis and repair
    - MTTF = means the time when the integral of the probability of failure curve until that point is 1/3 change to over 1/3
    - Availability = MTTF / (MTTF + MTTR) as %
      * MTTF, MTBF usually measured in hours
    - Since hope rarely down, shorthand is “number of 9s of availability per year”
      * 1 nine = 90% -> 36 days of repair/year
      * 2 nines = 99% -> 3.6 days
      * 3 nines = 99.9% -> 526 minutes
      * 4 nines = 99.99% -> 53 minutes
      * 5 nines = 99.99% -> 5 minutes
    - another is average number of failures per year: Annualized Failure Rate (AFR)
      * eg. 1000 disks with 100,000 hours MTTF  
        365 days \* 24 hours = 8760 hours   
        (1000 disks \* 8760 hrs/year) /100,000 = 87.6 failed disks per year on average
      * 87.6/1000 = 8.76% annual failure rate
* Dependability Design Principle
  + Design Principle: No single points of failure
    - “chain is only as strong as its weakest link”
  + Dependability Corollary of Amdahl’s Law
    - Doesn’t matter how dependable you make one portion of system
    - Dependability limited by part you do not improve
* Error Detection/Correction Codes
  + Memory systems generate errors (accidentally flipped-bits)
    - DRAMs store very little charge per bit
    - “Soft” errors occur occasionally when cells are struck by alpha particles or other environmental upsets
    - “Hard” errors can occur when chips permanently fail
    - Problem gets worse as memories get dense and larger
  + Memories protected against failures with Error Detecting Codes (EDC)/Error Correcting Codes (ECC)
  + Extra bits are added to each data-word (redundancy)
    - Used to detect and/or correct faults in the memory system
    - Each data word value mapped to unique code word
    - A fault changes valid code word to invalid one, which can be detected
* Block Code Principles
  + Hamming distance = difference in # of bits
    - Eg p = 011011, q = 001111, Ham. Distance (p,q) = 2
  + Extra bits as creating a code with the data
  + Parity: Simple Error-Detection Coding
    - Each data value, before it is written to memory is “tagged” with an extra bit to force the stored word to have even parity
      * Sum all of the bit values (without the parity bit) and see if it is even
        + If so, parity bit = 0
        + If not, parity bit = 1 to make it even
    - Each word as it is read from memory is “checked” by finding its parity (including the parity bit).
      * If sum with parity bit is even when reading, it is correct (no even number of errors)
    - Minimum Hamming distance of parity code is 2
    - A non-zero parity check indicates an error occurred:
      * 2 errors (on different bits) are not detected
      * Nor any even number of errors, just odd numbers of errors are detected
  + Hamming ECC
    - Set parity bits to create even parity for each group
    - create the coded word, leaving spaces for the parity bits
      * then replace spaces with calculated parity value
    - Single Error Detection (SED)
    - Double Error detection (DED)
  + What if more than 2-bit errors?
    - Network transmissions, disks, distributed storage common failure mode is bursts of bit errors, not just one or two bit errors
      * Contiguous sequence of B bits in which first, last and any number of intermediate bits are in error
      * Caused by impulse noise or by fading in wireless
      * Effect is greater at higher data rates
    - Solve with Cyclic Redundancy Check (CRC), interleaving or other more advanced codes
  + Hamming distance 2: Parity for Single Error Detection (SED)
  + Hamming distance 3: Single Error Correction Code (ECC) + Encode bit position of error
* Raid: Redundant Arrays of Disks
  + Redundancy yields high data availability
    - Availability: service still provided to user, even if some components failed
  + Contents reconstructed from data redundantly stored in the array if disks fail
    - Capacity penalty to store redundant info
    - Bandwidth penalty to update redundant info
  + RAID 1: Disk Mirroring/Shadowing
    - Each disk is fully duplicated onto its “mirror”
      * Very high availability can be achieved
    - Writes limited by single-disk speed
    - Expensive
    - Reads may be optimized
    - 100% capacity overhead
  + RAID 2: Memory + ECC
  + RAID 3: Parity Disk
    - Striped physical records
      * Parity disk contains sum of other disks per stripe mod 2(“parity”)
      * If disk fails, subtract P from sum of other disks to find missing information
  + RAID 4: High I/O Rate Parity
    - Does this with bytes instead of bits like in RAID 3
  + RAID 5: High I/O Rate Interleaved Parity
    - Interleaved parity to make possible independent writes
    - 1 logical Write = 2 Physical Read + 2 Physical Writes
      * can do a total of total number of disks/2 in parallel