### Embedded Systems and High Performance Computing (EPiC) Lab

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**Mission:** Algorithms for energy-efficient, fault-tolerant, and secure design of embedded systems (cyber-physical systems), mobile computing (smartphones, wearables, internet-of-things), and high performance computing (datacenters, supercomputers)

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**CAD Tools for Multicore Chip Design**

- Nearly all modern innovations depend on continued advances in multicore system-on-chip computing performance
  - Major impact on innovation across application domains: automotive, defense, medical, multimedia, telecommunications, aerospace, multidisciplinary computing

- But multicore system-on-chip design in advanced semiconductor fabrication technologies today faces several challenges
  - High power/energy dissipation that increases costs and limits achievable performance
  - Process, voltage, and temperature variations make it hard to model and verify high-performance designs
  - Increasing susceptibility to transient and permanent faults that degrade system reliability

**Network-on-Chip (NoC) Architectures**

- Design of on-chip communication fabric is a very critical factor influencing multicore chip performance, power, and reliability
  - NoCs have replaced on-chip buses, but face challenges
    - Higher packet transfer latency with increasing core counts
    - Higher power consumption and higher thermal impacts
  - Fault-tolerant NoC protocols and adaptation
    - tolerate NoC packet routing algorithms
    - Design for fault-tolerant communication for 2D NoCs
    - Design of self-healing NoC router fault-tolerant prototypes

**Memory Architectures**

- Improvement in dynamic memory bandwidth, but form factor is critical for next-generation multicore computing chips
  - To support increasing data demands from high-core-count chips, graphics processors, etc., the bus is becoming thread-speed limited
  - Challenges:
    - How to scale memory component density?
    - How to increase bandwidth and reduce latency?
    - How to best store programs and data?

- New 3D DRAM architectures
  - 3D-DRAM stack: highe bandwidth and reduced power
  - Novel vertical stacking to significantly improve performance and reduce power consumption

**Automotive Embedded Systems**

- Vehicles are controlled by distributed, real-time embedded systems
  - Many embedded systems use cloud computing
  - Major challenge in designing a safety-critical system that support cloud computing as well as supercomputers that solve large scientific problems: need for energy-efficient operation
  - Many embedded systems use cloud computing
  - Major challenge in designing datacenters that support cloud computing as well as supercomputers that solve large scientific problems: need for energy-efficient operation
  - Energy costs today = $1/year/TPF
  - Can we reduce energy costs?

**High Performance Computing**

- Energy Efficient and Robustly Robust Resource Allocation
  - Workload and system uncertainty modeling
  - Need to balance multiple goals while satisfying design constraints
  - Fault-tolerant NoC protocols and adaptation
  - Need to balance multiple goals while satisfying design constraints
  - Speed of light latency, low power, high throughput
  - Challenges:
    - Process variations
    - Thermal variations
    - Protocol design
    - Inter-router and intra-router communication
    - Dynamic voltage/frequency scaling (DVFS) for CPU energy saving during idle periods

**Mobile Computing**

- Energy demands and capabilities of ‘smart’ mobile devices are increasing rapidly with growing mobile app complexity
  - But battery technology is lagging behind and is expected to continue to be a limiting factor for future growth of mobile devices such as smartphones
  - How to intelligently manage energy and improve battery life for mobile devices?

- Need new CAD tools to perform multi-objective chip design exploration and optimization
  - Novel CAD tools for emerging 2D/3D multicore chip design
  - Design-time multi-core and multi-thread architectures
  - Advance driver assistance systems (ADAS) algorithms and prototyping
  - Mobile robotic embedded systems
  - Mobile computing
  - CAD Tools for Multicore Chip Design
  - Network-on-Chip (NoC) Architectures
  - Memory Architectures
  - Cybersecurity and high-performance computing

**Energy Harvesting IoT Platforms**

- Solar energy harvesting can power many IoT and embedded systems
  - How to scale software applications to mobile platforms under various conditions and energy harvesting conditions that often vary dramatically
  - How to cope with thermal environments?
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- Another major challenge: ensuring fault-resilient operation
  - How to efficiently and effectively recover from transient faults?
  - Robustness exploration/management for extreme-scale HPC
  - Analysis of checkpointing, redundancy based techniques
  - Co-design of resilience strategies with scheduling schemes

**Embedded System Applications and Prototypes**

- Medical and rehabilitation centric embedded systems
  - Medical and rehabilitation centric embedded systems
  - Mobile robotic embedded systems
  - Mobile computing (smartphones, wearables, internet-of-things)

**Graduate Students**

- Existing design methods are insufficient for high-performance computing in modern embedded systems
  - Models for SoC design must be extended to include thermal and energy effects
  - How to best manage power dissipation?

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