Bluehive: A Scalable Platform for Million-Scale Real-Time Neural Computation
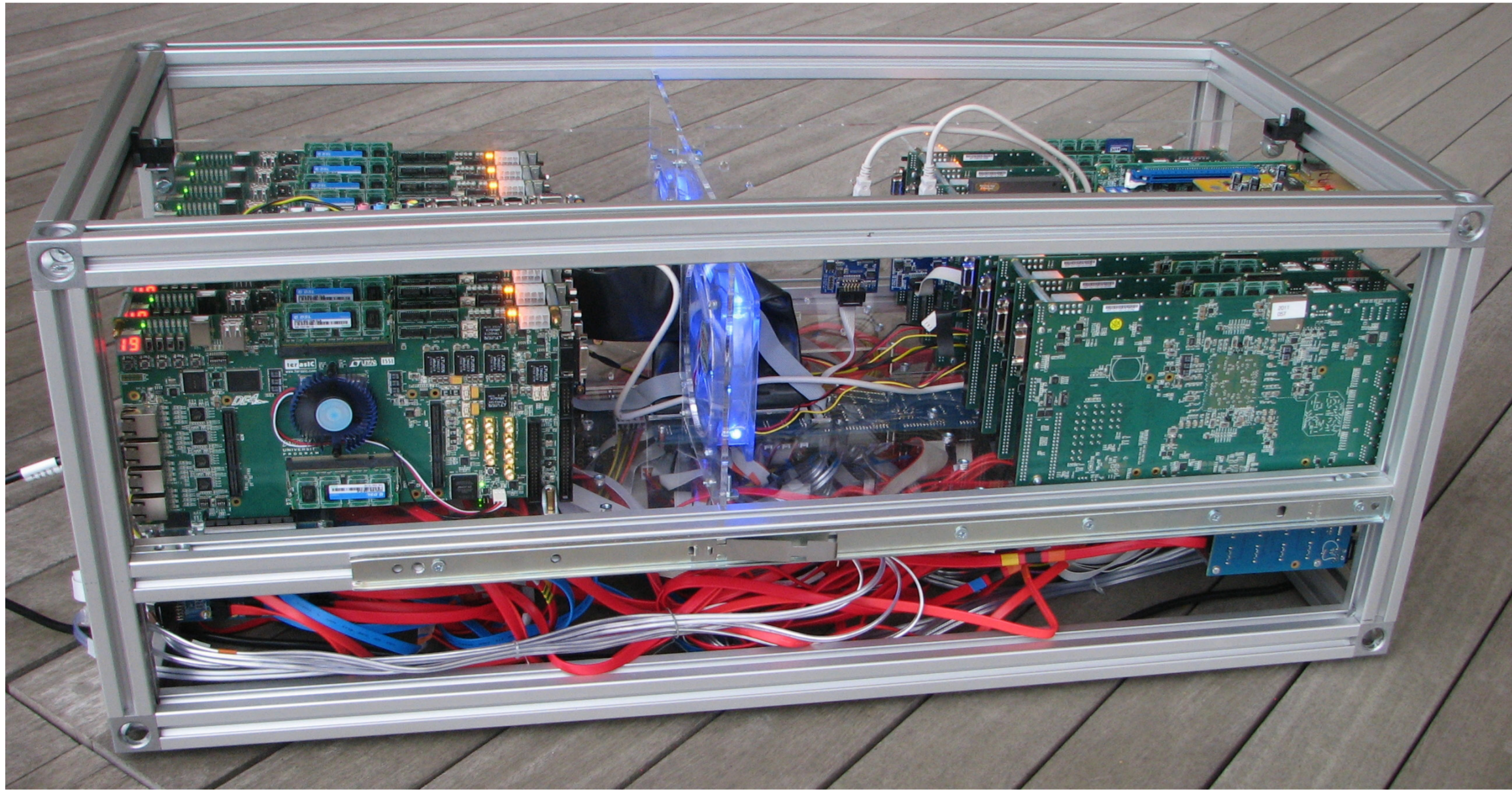
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Hardware

Introduction

Bluehive is a custom 64-FPGA machine targeted at real-time neural computation exceeding one million neurons.
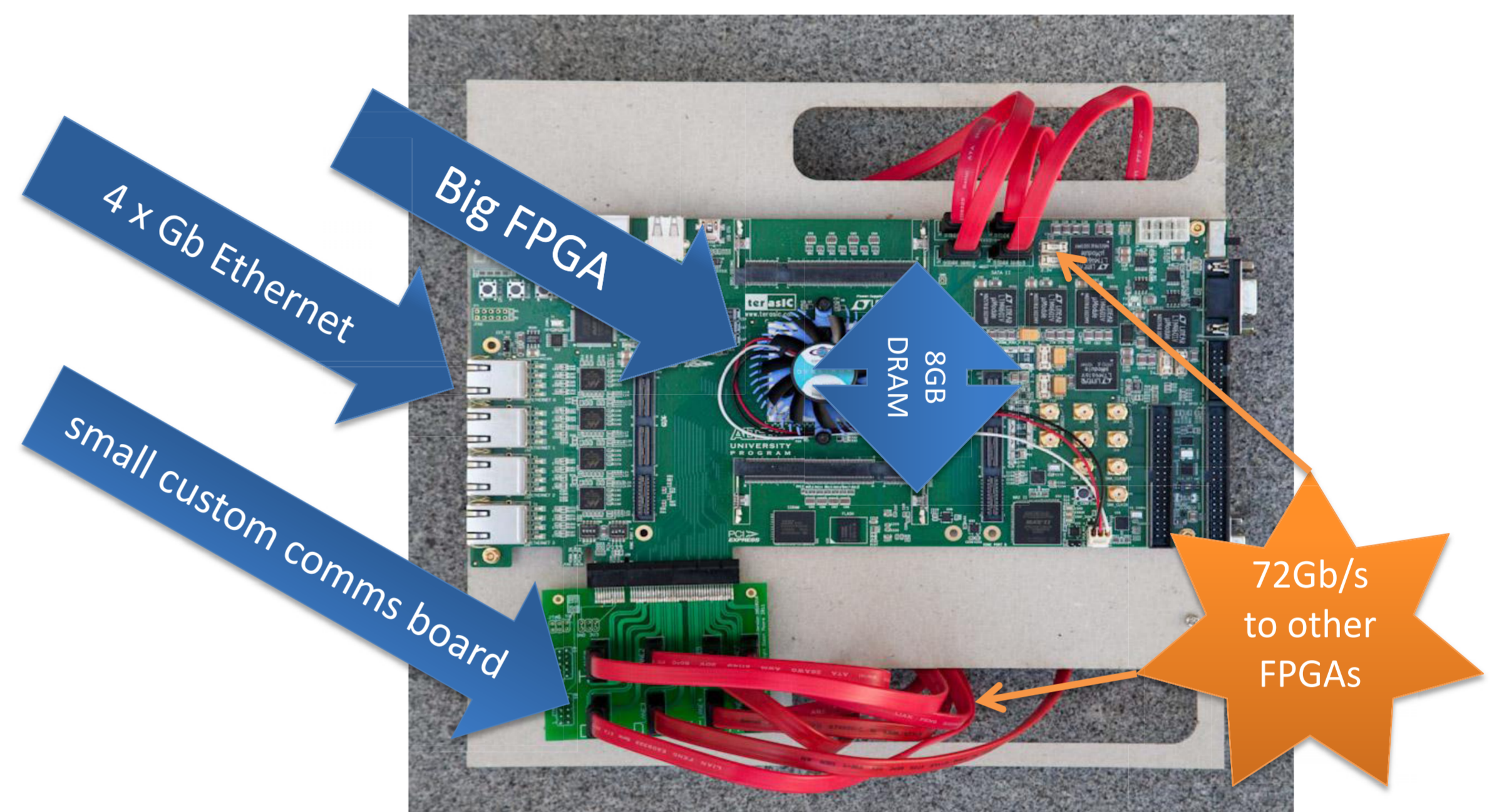
Bluehive is:
- Highly scalable and extensible with reconfigurable communication topology
- Suited to algorithms with demanding high-bandwidth and low-latency communication — unattainable with commodity CPUs and GPGPUs
- Initially targeting the Izhikevich spiking neuron model but work is under way to extend to other models

1× 16-FPGA Bluehive box provides:
- Up to 1 million Izhikevich neurons in real-time
    1,000 synaptic connections per neuron
    1 millisecond sampling interval
    Smaller networks faster than real-time
- 16 Altera Stratix IV FPGAs
- 1.5 terabit/s low-latency communication
- Up to 128GB DDR2 DRAM
- 64 gigabit ethernet ports

One Bluehive FPGA

4 x Gb Ethernet · Big FPGA · 8GB DRAM · small custom comms board · 72Gb/s to other FPGAs
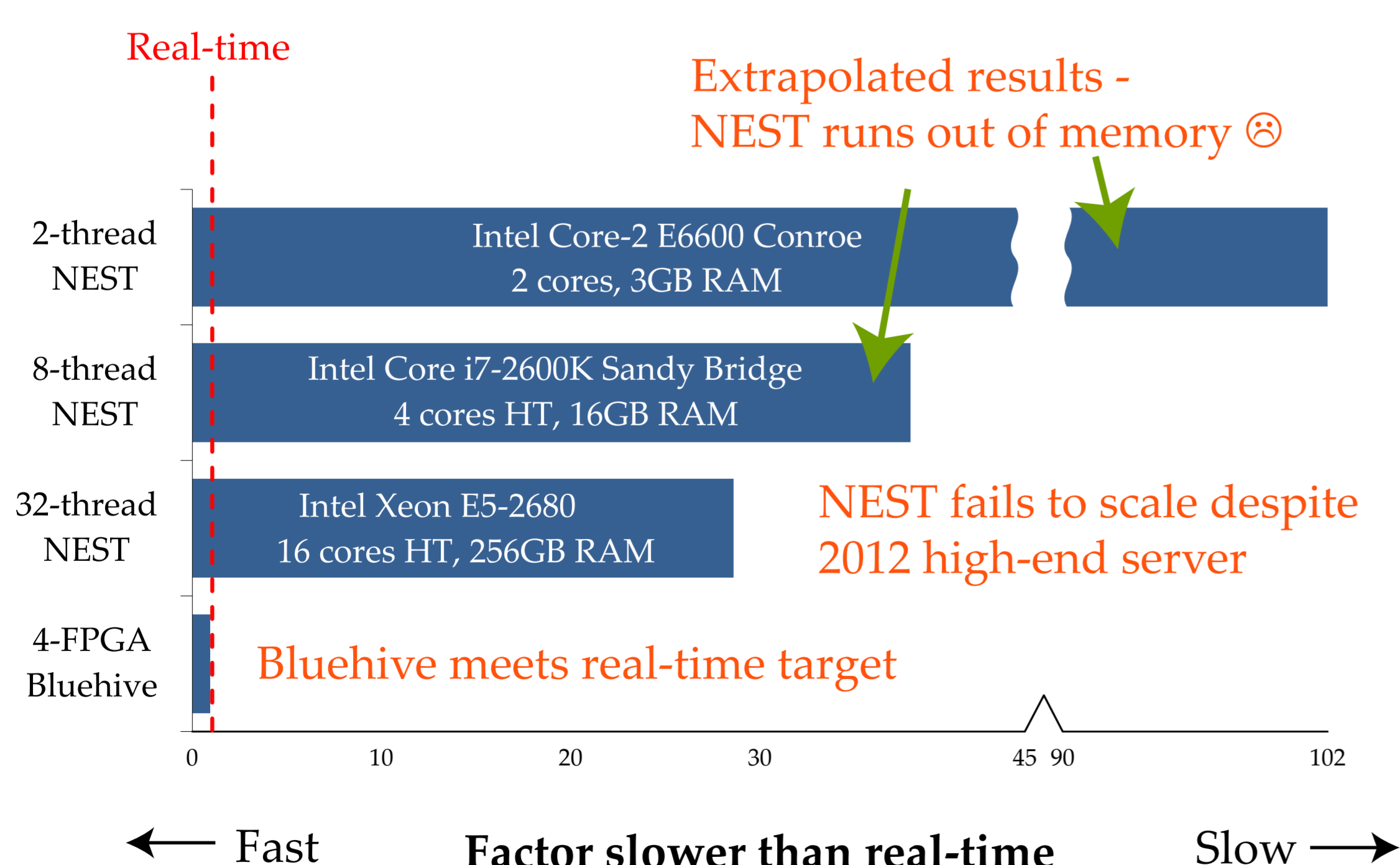
Architecture
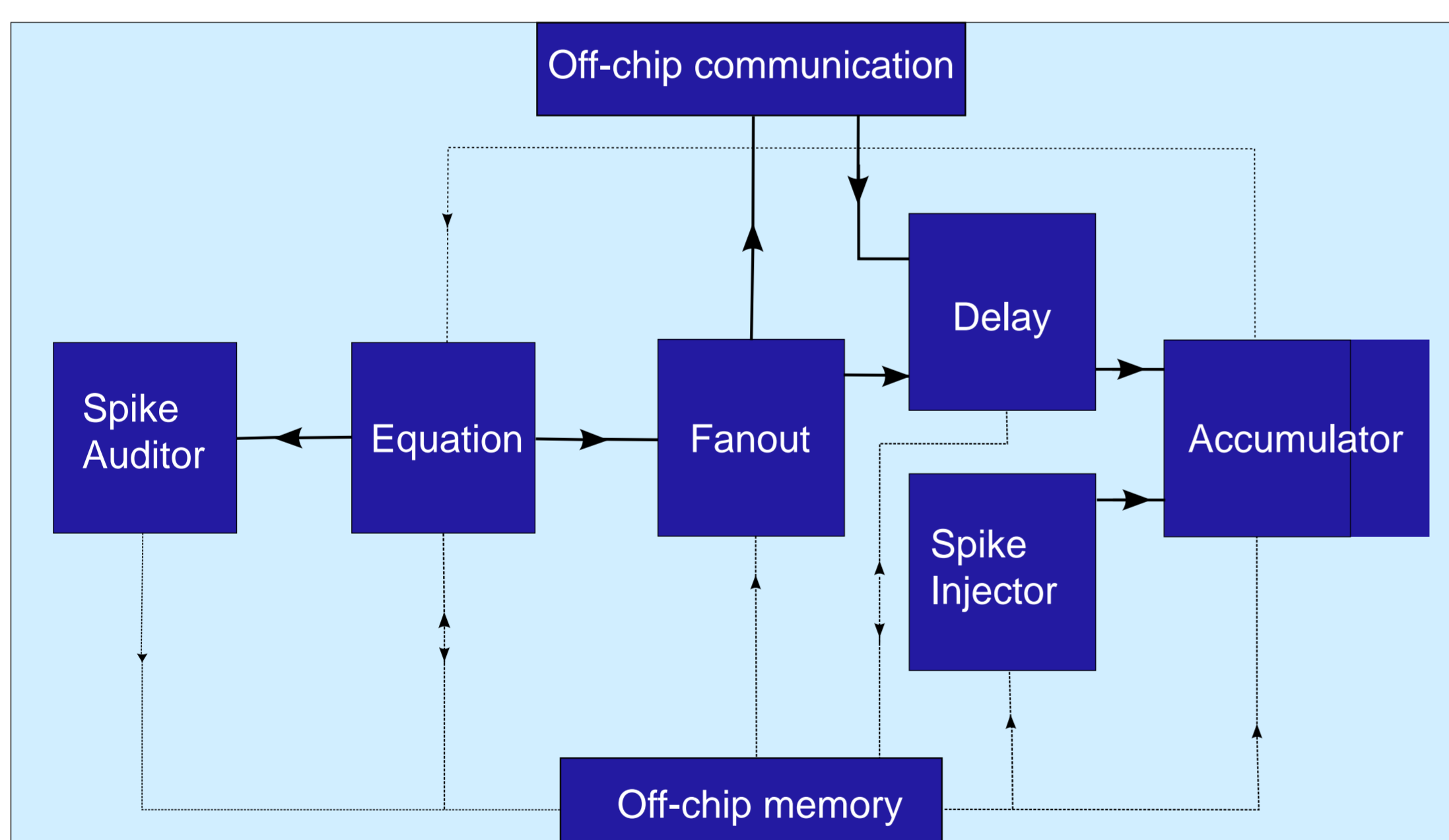
- Spiking neuron algorithm mapped to FPGA using a communication-centric approach, in BlueSpec SystemVerilog
- Optimised for best use of FPGA and DDR2 memory
- Contrasts with many FPGA systems focused on parallel computation — inefficient use of FPGA resources
- 64K neurons with 64M synapses per FPGA, scales to large numbers of FPGAs.

Users wanted! Could you make use of the Bluehive? Please get in touch!

Performance

Bluehive v PC for 256K neurons

Real-time · Extrapolated results - NEST runs out of memory ☹

- 2-thread NEST — Intel Core-2 E6600 Conroe 2 cores, 3GB RAM
- 8-thread NEST — Intel Core i7-2600K Sandy Bridge 4 cores HT, 16GB RAM
- 32-thread NEST — Intel Xeon E5-2680 16 cores HT, 256GB RAM
- 4-FPGA Bluehive

NEST fails to scale despite 2012 high-end server

Bluehive meets real-time target

← Fast   **Factor slower than real-time**   Slow →

Scalability

Real-time

NEST on 16-Core Intel Xeon — 64k neurons, 128k neurons, 256k neurons

NEST encounters bottleneck despite substantial compute resources

Bluehive:
- 1 FPGA — 64k neurons
- 2 FPGAs — 128k neurons
- 4 FPGAs — 256k neurons

Bluehive scales linearly by adding FPGAs and continues to meet real-time target

← Fast   **Factor slower than real-time**   Slow →